OPTIMIZATION AND CHARACTERIZATION OF INSTANT PORRIDGE DEVELOPED FROM RICE-PIGEON PEA FLOUR BLEND

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DEPARTMENT OF BIOCHEMISTRY
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APRIL, 2018

DECLARATION

I hereby declare that the work in this dissertation entitled "**Optimization and Characterization of Instant Porridge Developed from Rice-Pigeon Pea Flour Blend"** was carried out by me in the Department of Biochemistry. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation has been previously presented for another Degree or Diploma in this or any other institution.

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Mohammed Banki NDALIMAN Name of Student	Signature	Date

CERTIFICATION

This dissertation entitled "**Optimization and Characterization of Instant Porridge Developed from Rice-Pigeon Pea Flour Blend"** by Mohammed Banki NDALIMAN meets the regulations governing the award of the Degree of Master of Science in Nutrition of the Ahmadu Bello University Zaria, and is approved for its contribution to knowledge and literary presentation.

Dr. A. Salihu Chairman, Supervisory Committee	Signature	Date
Dr. A. Muhammad Member, Supervisory Committee	Signature	Date
Prof. M.N. Shuaibu Head of Department	Signature	Date
Prof S.Z. Abubakar Dean, School of Postgraduate Studies, Ahmadu Bello University, Zaria.	Signature	Date

DEDICATION

I dedicated this dissertation to Allah (SWT) and to my lovely wife, Fatima Musa Ginya for her patience, moral support, encouragement and prayers. May Almighty Allah reward you with the best of his Favour (Aameen)

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ABSTRACT

Extrusion cooking was used to formulate rice and pigeon pea blend with the aim of providing high energy, protein enriched and affordable foods for malnourished children. Three (3) factors (screw speed, feed moisture content and feed blend composition) affecting the extrusion cooking process were subjected to Central composite design (CCD) and functional properties were used to optimize production variables. Furthermore, the expansion index of 9.56 ± 0.15, bulk density of 0.05 ± 0.01 g/ml and water absorption index of 5.55 ± 0.07 at screw speed of 200 rpm, feed moisture content of 30 % and feed blend composition of 20% (run 12) were obtained. Regression model and response surface plots were developed and tested via coefficient of determination (R^2 and adjusted R^2), analysis of variance, lack of fit and residual plots. The developed quadratic model showed significant ($p<0.05$) effect of the process variables on the functional properties of instant porridges from rice-pigeon pea flour blend. Similarly, the coefficient of determination (R^2) was found to be 0.96, 0.93, and 0.88, for expansion index, bulk density and water absorption index of the extrudates. Furthermore, lack of fit for the quadratic models were not significant ($p>0.05$), which suggested that the model equations were adequate in describing the functional properties of the rice-pigeon pea extrudates. In order to optimize the quadratic models, four formulations were prepared and subjected to nutritional and sensory properties where formulation 3 showed higher protein (22.10 ± 0.01 g/100g), limiting amino acids, (lysine and methionine) of 3.44 ± 0.04 g/100g and 1.44 ± 0.02 g/100g, calcium (3.41 ± 0.07 mg/100g), iron (12.64 ± 0.03 mg/100g), zinc (9.33 ± 0.02 g/100g) contents and general acceptability (6.68 ± 0.06). In conclusion, convenient complementary food was developed from rice-pigeon pea flour blend through extrusion which improved the nutritional and sensory properties of the products.

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LIST OF ABBREVIATIONS

ADP	Agricultural Development Project
ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemist
ARC	Africa Rice Centre
ATA	Agricultural Transformation Agenda
BD	Bulk Density
CCD	Central Composite Design
FBC	Feed Blend Composition
FMC	Feed Moisture Content
HTST	High Temperature Short Time
NACGRAB	National Centre for Genetic Resources and Biotechnology
NASC	National Seed Council
NERICA	New Rice for Africa
OFN	Operation Feed the Nation
RBDA	River Basin Development Authority
R^2	Coefficient of determination
RTUF	Ready to use Therapeutic Foods
SAP	Structural Adjustment Programme
SEI	Sectional Expansion Index
SSP	Screw Speed
WAI	Water Absorption Index
WARDA	West African Rice Development association
WFP	World Food Programme

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Food processing technology via locally available raw materials and innovative processing technologies that maintain high nutrient compositions and consumer acceptability have been extensively studied (Singh *et al.*, 2000; Anuonye, 2012; Filli *et al*., 2013). Cereals and legumes are the principal sources of energy and protein for significant population in developing countries including Nigeria (Muller and Krawinkel, 2005). The production of cereal-legume based products to supply additional protein and minerals has increased significantly over the years (Muller and Krawinkel, 2005). Extrusion cooking technology has played a central role in enhancing food security for development of different types of products such as breakfast cereals, flakes, quick cooking paste, instantised legume powders and breakfast gruels (Chaiyakul and Winger, 2009). This technology requires a high temperature short time (HTST) cooking process which provide an alternative for improving traditional food processing (Guy, 2001a). It also has the ability to produce a shelf-stable food of reduced microbial load, minimal anti-nutrient content and low moisture content. (Filli *et al.*, 2011). Products with these characteristics are suitable for countries like Nigeria where infrastructure is limited and inadequate (Filli *et al.*, 2011).

Extrusion method is one of the contemporary food processing technologies applied to foods in order to mitigate the problems associated with processing of traditional cereal based-products in terms of functional properties, physical state and shelf-life (Guy, 2001a). It offers many advantages over spray-drying and roller-drying technologies in terms of preparation of ready-to-eat foods of desired shape, size, texture and sensory characteristics at very low processing cost (Guy, 2001a; Sumathi *et al.*, 2007).

Rice (*Oryza sativa*) is an important food crop in the world and the number of consumers depend on it as their staple food (Juliano, 2016), which could be linked to its attractive color, bland taste, hypoallergenicity and ease of digestion (Guy, 2001). It has been reported that an average Nigerian, consumes 21 kg of rice per year (WARDA, 2004). In most developing countries, rice accounts for daily supply of 27% of energy, 20% of protein and 3% of fat (Kennedy and Burlingame, 2003). Similarly, extruded products from rice are currently less available compared to those from maize and wheat (Danbaba *et al.*, 2015). Guha and Ali (1998) reported that the free glutinous rice is suitable material for production of the extruded products such as ready-to-eat snacks and breakfast cereal with low bulk density, high expansion and low shear stress.

Pigeon pea (*Cajanus cajan)* is an indigenous crop and one of the major leguminous crops cultivated in many countries of the tropics and subtropics (Troedson *et al.,* 1990). It is known as *Waken Kurawa* in Hausa, *Fio fio* in igbo and *Otilli* in yoruba (Anuonye *et al*., 2012). Similarly, it is considered as number four after groundnut, cowpea and Bambara nut and highly cherished for its protein content (17 - 30%) which makes it indispensable along with cereals in human diet (Troedson *et al.*,1990). The plant has also been listed as one of the under-utilized legumes with broad potentials and its seed could serve as an ideal supplement to traditional african cereal and tuber-based diets which are generally protein deficient (Badifu, 1992; Onu and Okongwu, 2006; Eneche, 2009). Therefore, blending of rice and pigeon pea will produce adequate meals of balanced nutrient compositions for both infant and adult usage.

1.2 Statement of Problem

In Africa, poverty, poor agricultural practices, low productivity and inadequate processing are the major causes of food shortage (Danbaba *et al*., 2015). Based on this, significant populations survive predominantly on staple food crops such as rice, maize, sorghum, millet, cassava, with little or no animal products to meet the protein need for normal growth and development (Danbaba *et al.*, 2015). These problems are further aggravated by the menace of epidemic diseases that increased the number of vulnerable populations, which resulted in wide spread of maternal and infant malnutrition in most of the countries (Danbaba *et al.*, 2015). Despite Africa's vast natural resources and a considerable progress in economic growth; hunger and malnutrition have remained endemic amongst the African population, and it is estimated that 200 million Africans are chronically malnourished (WFP, 2011; Mohammed, 2017).

Similarly, several strategies have been adopted to reduce maternal and infant malnutrition including diversification, fortification and complementation of foods with indispensable amino acid sources, supplementation with good quality protein and the utilization of locally grown crops for the production of high protein, shelf stable and affordable recipes for addressing the deepening global nutrition challenges in developing countries (Iwe, 2001).

1.3 Justification of the Study

The production of cereal-legume based products provides an ideal source of dietary protein for human populations; such products include nutritionally enhanced biscuits, breads, cakes, porridges and extruded snacks (Filli *et al*., 2011). Nutritionally, rice and rice-based products are deficient in lysine, an essential amino acid, that can easily be improved by blending rice with food materials rich in lysine.

In addition, researches on utilization, development and commercialization of pigeon pea and its associated products are limited in Nigeria when compared with other legumes such as cowpea (Akande, 2007). However, several researches have been reported on the use of extrusion cooking for cereals and legumes singly (Bredie *et al*., 1998; Iwe, 2001; Pelembe *et al*., 2002; Ding *et al*., 2006), and no available report in the literature to the best of our knowledge on the development of rice-pigeon pea blend using this technology.

Hence, extrusion technology could contribute in this direction through the production of foods containing cereals and legumes, which are highly acceptable, and meet consumer's specifications. Furthermore, extrusion processes could help in producing quality products with improvement in nutritive value, colour, flavor and bioactive substances as well as reduction in production cost (Tabo *et al*., 1995).

1.4 Aim and Objectives

The aim of this research is to optimize and characterize instant porridge developed from rice-pigeon pea flour blend using extrusion cooking method.

1.4.1 Specific Objectives

i. To determine the optimum process conditions for production of instant porridge from rice- pigeon pea flour blend using statistical optimization technique.

ii. To evaluate the characterization on proximate, amino acid and mineral compositions of the developed instant porridge from rice-pigeon pea flour blend.

iii. To carry out sensory evaluation of the developed instant porridge from rice- pigeon pea flour blend.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin of Rice

Rice is the monocot seed plant of the genus *Oryza* and of the grass family Poaceae (formally Graminae) which includes twenty wild species and two cultivated ones; *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice) (Oko and Ugwu, 2011). *Oryza sativa* is the most commonly grown species throughout the world today. Rice has been considered as the best staple food among all the cereals and is the staple food for over three billion people constituting over half of the world's population (Oko and Ugwu, 2011). Rice grows from the Equator of Latitudes 53^{o}N (in China) and 35 – 40^{o}S to elevations (in tropical regions) as high as 2400 meters above sea level (Kenmore, 2003). Rice is the world's most consumed cereal after wheat with ability to provide more than 50% of the daily calories requirements (Sun *et al.*, 2006).

Rice (*Oryza sativa*) is recognized as a source of starch in the diet and is generally consumed as either whole grain or as flour ingredients. Rice varieties have different qualities that suit different food formulations. However, the selection of grains in the market place using physical grain qualities includes grain shape, translucency and whiteness of the grain (Ward, 2009). In addition to these; rice consumers have preference to some selected cooking qualities, such as texture when hot and cold, cooking time and digestibility (Ward, 2009).

2.2 Rice Distribution

Rice (*Oryza sativa*) was probably first domesticated in the Yangtze River Valley in China (Vaughan *et al.*, 2008), perhaps about 7000 years ago, before it spread to other parts of Asia. Rice has been cultivated, gathered and consumed by different people worldwide for more than 10, 000 years i.e longer than any other crop (Kenmore, 2003). The general consensus is that, rice domestication occurred independently in China, India and Indonesia, thereby giving rise to three races of rice; *sinica* (also known as *japonica*), *indica* (in India) and *javanica* (also known as *bulu* in Indonesia). In the beginning, rice grew wild, but today most countries cultivate different varieties belonging to the *Oryza* type which has around twenty different species (Kenmore, 2003). Only two of them offer agricultural interest to humans; *Oryza sativa* is common Asian rice found in most rice producing countries which originated in the far east at the foot of the Himalayas. Thus, *O. sativa japonica* grew on the Chinese side of the mountains and *O. sativa indica* on the Indian side. The majorities of the cultivated varieties belong to this species, and are characterized by their plasticity and taste qualities. *Oryza glaberrima* Steud, an annual species originating in West Africa covering a large region extending from the central Delta of the Niger River to Senegal between 1500 and 800 B.C (WARDA, 2004). However, its cultivation declined in favour of the Asian species possibly brought to the African continent by the Arabians coming from the East Coast from the $7^{th}$to 11^{th}centuries (WARDA, 2004).

2.3 Rice Varieties

The TXD306 is a high yielding variety with an improved grain quality and highly aromatic which is preferred by consumers and farmers (MAFC, 2009). The TXD85 and TXD88 varieties lack acceptable aroma notwithstanding being endowed with improved grain quality and high yielding properties improved from the *O. sativa* species (MAFC, 2009). In New Rice for Africa (NERICA) varieties, West Africa Rice Development Association found it is highly necessary to combine the toughness of *O. glaberrima* due to its rich reservoirs of genes for resistance to local stresses (although low yielding) with *O. sativa,* the productive one in spite of its low adaptability to rain–fed uplands (WARDA, 2004). This was a formidable scientific challenge which had resulted in the failure of previous attempts to develop a reliable variety since the two species have evolved separately over millennia and is so different (WARDA, 2004). NERICA has unique combined assets such as: higher yields (by 50% without fertilizer and more than 200% with fertilizer), early maturity (by 30 – 50 days), resistance to local stresses and higher protein content (WARDA, 2004).

2.4 Global Rice Production

Rice is grown and harvested on every continent (Abbas *et al.*, 2011) and it is one of the leading crops globally in terms of importance as a staple food (Toriyama *et al.,* 2005). The world's population exceeds 6.5 billion individuals and over half are dependent on rice for at least a portion of their diet (Fairhurst *et al*., 2007). The majority of all rice produced comes from India, China, Japan, Indonesia, Thailand, Burma and Bangladesh (Fairhurst *et al.*, 2007). Rice cultivation is the principal activity and source of income for millions of households around the globe and several countries of Asia and Africa are highly dependent on rice as a source of foreign exchange earnings and government revenue (Paranthaman *et al.,* 2009). Asia is the biggest rice producer accounting for 90% of the world's production and consumption (Paranthaman *et al.,* 2009). China and India which account for more than one–third of global population supply over half of the world's rice. The global rice cultivated area was forecasted to rise by 1.5% from 156.3 to 158.6 million hectares and the yield by 2.4% from 4.2 to 4.3 tonnes of paddy per hectare (Juliano, 2016).

2.5 Rice Production in Africa

Rice has become a strategic significant commodity across the Africa which is driven by changing food preferences in the urban and rural areas as a result of high population growth rates and rapid urbanization (Juliano, 2016). According to Juliano (2016) statistics reported in the Rice Market between 2000 and 2008 that production of milled rice grew by 59% while consumption grew to 38% increase (Juliano, 2016). However, rice statistics in West Africa are notoriously unreliable and other analysts maintain that, the gap between production and consumption is actually growing (Campbell *et al.*, 2009). According to Wilfred and Consultant (2006), rice is the main staple food of the populations in Cape Verde, Comoros, Gambia, Guinea, Guinea–Bissau, Liberia, Madagascar, Egypt, Reunion, Senegal and Sierra Leone and is also an important food for the populations in Côte D'Ivoire, Mali, Mauritania, Niger, Nigeria, and Tanzania. In addition, rice has become an important food security factor in Angola, Benin, Burkina Faso, Chad, Ghana, Uganda and Nigeria.

2.6 Rice Production in Nigeria

Nigeria is the largest rice producing country in the West African (Berhe, 2005). Rice production in Nigeria rose gradually over the years to surpass major rice producing countries like Cote D'Ivoire, and Sierra Leone (Berhe, 2005). In 2002, Nigeria accounted for nearly 44% of the total rice output and 57% of the total rice producing area in West Africa.

According to FAO (2010), the Nigerian rice sub-sector witnessed a remarkable increase in output from 2.5 million metric tonnes in 1990 to about 4.2 million metric tonnes in 2008. The principal factors driving increased rice production in Nigeria was population growth and urbanization (Berhe, 2005).

In response to the prevailing rice supply deficit situation in the country, successive Nigerian governments have intervened in the rice sub-sector, by increasing tariff on rice importation so that local production could be encouraged (Bamidele *et al*., 2010). This was expected to widen the home market for the nation's local rice (Bamidele *et al*., 2010). The Federal government of Nigeria also established research institutions and programmes geared toward increasing rice production. These included the National Cereals Research Institute (NCRI) at Badeggi in 1974, National Seed Council (NASC) at Sheda, Abuja in 1975, and Operation Feed the Nation (OFN) programme in 1976, the River Basin Development Authorities (RBDAs) in 1977, Agricultural Development Projects (ADP) in 1975, Structural Adjustment Programme (SAP) in 1986 and the Presidential Initiative on increased rice production, processing and export in 2002 (Bamidele *et al*., 2010).

These agricultural programmes have common objectives of increasing production and productivity in the rice sub-sector, thereby achieving food self-sufficiency. The Nigerian government has also embarked on an ambitious plan to make the country self-sufficient in rice production by 2018 under its current Agricultural Transformation Agenda (ATA) (Adesina, 2012). This initiative is in response to the perceived threat of larger volume of milled rice imports into Nigeria since the 1990s. The potential for Nigeria to succeed in its quest to become self-sufficient in rice production depends a lot on how well the government maintains its policies and invests in the sector. Thus, there is a high level of political will and leadership to change attitudes towards transforming the rice sector and the rural economy more broadly. (Adesina, 2012). Another positive sign is the unprecedented attention being given to improving the post-harvest segment of the rice value chain in order to improve quality and compete more effectively with imports (Adesina, 2012). Today, rice is cultivated in virtually all the agro-ecological zones in Nigeria, but on a relatively small scale. For example, in 2010, out of about 25 million hectares of land cultivated for various food crops, only about 6.7% was used for rice production. The trend in production shows that rice output increased from 27 million hectares to 38 million hectares in 2014-2015 (Imolehin and Wada, 2016).

Presently, Nigeria is facing two key gaps in agriculture today: an inability to meet domestic food requirements, and an inability to export at quality levels required for market success. The former problem is a productivity challenge driven by an input system and farming model that is largely inefficient. As a result, an aging population of farmers do not have enough seeds, fertilizers, irrigation, crop protection and related support to be successful (Ogbeh, 2017). Similarly, the new federal Agricultural Promotion Policy (APP) is a strategy that focuses on solving the core issues at the heart of limited food production and delivery of quality standards. As productivity improves domestically and standards are raised for all Nigerian food production, export markets will also benefit impacting positively on Nigeria's balance of payments (Ogbeh, 2017).

2.7 Rice Quality

Rice grain quality is determined by a combination of varietal properties and environmental conditions which occur during crop production, harvesting, processing and handling (Gummert, 2010). Varietal properties include: chemical characteristics (gelatinization temperature, apparent amylose content, gel consistency, alkali spreading value and aroma); physical characteristics are shape and size, colour of grain (Figure 2.1), chalkiness, bulk density, thermal conductivity, equilibrium moisture content and grain flow–ability (IRRI, 2010). Environmental properties are either additional to the normal varietal qualities or are the consequence of certain varietal qualities being lost or modified during processing (Gummert, 2010). Important environmental properties are: moisture content, grain purity, physical and pest damage, cracked grains, presence of immature grains (IRRI, 2009). The milling related characteristics (head rice recoveries, grain dimensions, whiteness, milling degree and chalkiness) are likely affected by environmental changes (Siebenmorgen *et al.*, 2007). Milling related characteristics are relevant measures of value because these are of major concern to consumers (IRRI, 2009).

Rice quality therefore, can be divided into five broad descriptive categories; these interrelated categories are milling quality, cooking and eating quality, processing quality, nutritive quality and purity/cleanliness standards (Siebenmorgen *et al.,* 2007). Each category is described by a specific set of criteria that collectively determine the suitability of rice for a specific end–user. The quality of grain is best when it reaches the physiological maturity (Pan *et al.,* 2007).

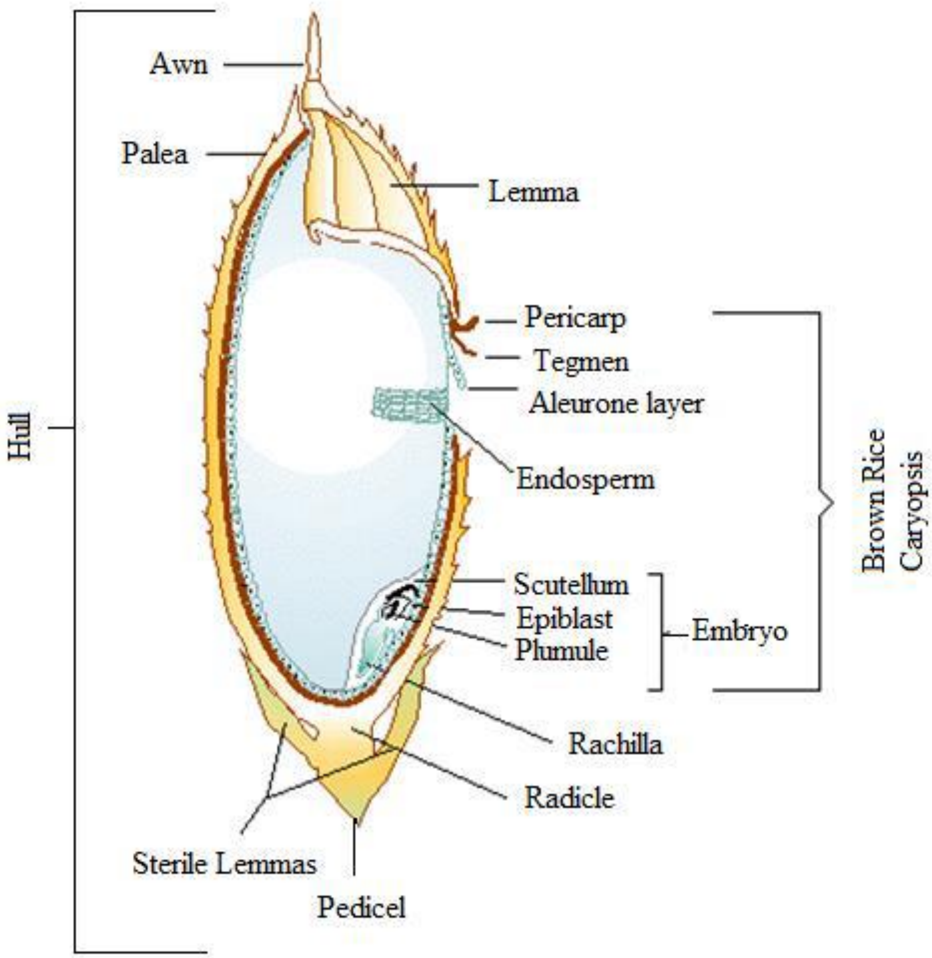


Figure 2.1: Morphology of Rice grain (IRRI, 2009)

2.8 Chemical Composition of Milled Rice

Chemical composition of food is important and for cereal the highest percentage proximate composition is carbohydrate followed by crude protein, moisture, crude fibre, ash and fat (Edeogu *et al.,* 2007). The degree of milling and polishing determines the amount of nutrients removed. Rice grain quality affects the nutritional and commercial value of the grains, and is of immense importance to those involved in producing, processing and consuming rice (Yi *et al.,* 2009). Rice quality does not only imply the physical appearance or qualities, rather it encompasses both, the chemical and cooking characteristics; therefore, it is necessary to include the nutritional values derivable from rice into consideration when choosing a particular rice variety (Oko and Ugwu, 2011).

Rice at 12 % moisture content contains approximately 80% starch and 7% protein (Wells, 1999). Polished rice is mainly made up of starch, protein, lipid and moisture. The protein content of polished rice in 22 Japonica rice varieties ranged from 5.9 to 7.9% and 6.0 to 13.6 % in brown rice among Chinese Japonica varieties (Lestari *et al.*, 2009). Starch occurs in the endosperm as small many-sided granules while protein is present as particles that lie between the starch granules (Huang *et al.*, 1998). Rice grain also contains sugars, fat, dietary fibre and minerals. The determination of food composition is fundamental to theoretical and applied investigations in food science and technology (Aganga and Tshwenyane, 2004). This is often the basis for establishing the nutritional value and overall acceptance of the food from the consumers' stand point (Aganga and Tshwenyane, 2004). Similarly, Juliano (2016) reported that moisture content of 14.0% is safe for storage and nutritional quality. The nutrient content is affected when the moisture content is above the critical value of between

16.0 % depending on the variety. Furthermore, rice has one of the lowest protein contents (7 %) among the cereals Juliano (2016). The bran layers and embryo are richer in nonstarch constituents, high in dietary fibre than the milled rice. The major nutritional advantage of brown rice over milled rice is as a result of higher vitamin B content. Although higher in mineral content, but phytic acid forms complexes with minerals and proteins, thereby reducing their bioavailability. Thus, the available iron is similar in brown and milled rice, but probably higher in brown rice for zinc than milled rice. The energy content of brown rice and bran is higher than that of milled rice, owing to the higher fat content Juliano (2016).

2.9 Origin and Production of Pigeon Pea

The pigeon pea (*Cajanus cajan*) belongs to the legumniosae family of flowering plants. It is an erect woody short perennial shrub which grows in semi-arid and sub-humid tropics. It is grown in Africa, including Nigeria, India, the Caribbean, and South America (Sharma *et al*., 2011). In Nigeria, it is grown extensively in Enugu, Anambra and Benue states (Anuonye *et al*., 2012). It is called "*fio-fio"* in Igbo, and "*Waken Kurawa"* in Hausa and "*Otili"* in Yoruba (Anuonye *et al*., 2012). The pigeon pea seeds are contained in pods which are flattened and about 4-10cm in length and 0.6-1.5cm width. The colour of the pod is green, purple or maroon and each pod contains about two to eight seeds (Enwere, 1998). The seeds from different varieties or cultivars vary in shape, size and colour of the testa. The shapes may be spherical, oval or kidney shaped (Plate 2.1). The colour of the testa of mature dry seed is dirty white, cream brown, dirty grayish white, pink, purplish-black or mottled (Enwere, 1998) as indicated in Plate 2.1.

Plate 2.1: Pigeon pea seeds and their Morphology (Saxena, 2010).

2.10 Nutritional Content of Pigeon Pea

The world annual production of pulses is estimated at 57.5 million metric tonnes (Saxena, 2010). Pigeon pea (*Cajanus cajan*) accounts for about 5% of the world's pulse production (Opoku *et al.*, 2003; Saxena, 2010; Sharma *et al.*, 2011). It finds an important place in the farming systems adopted by subsistent farmers in a number of developing countries (Opoku *et al.*, 2003; Sharma *et al*., 2011). Pigeon pea flour has been tested and found to be suitable as a protein source for supplementing cereal food products due to its high level of protein, iron and phosphorus (Harinder and Sharma, 1999). It has been recommended for school feeding programme and vulnerable sections of the population in developing nations (Harinder and Sharma, 1999).

Typically, the average nutritional composition of pigeon pea is 29.2% protein, 57.3% carbohydrate, 1.5% fat, 8.1% fiber and 3.8% ash (Roy *et al.*, 2010). Pigeon pea can be consumed as dehulled splits, whole, canned, boiled, roasted or ground into flour to make a variety of desserts, snacks and main dishes (Sharma *et al*., 2011). Mature and dried pigeon peas require long cooking hours. The hard pigeon pea seed coat contributes to the long cooking hours and dehulling reduces the cooking time (Sharma *et al*., 2011). The seed coats are high in fibre, low in nutrients and digestibility. Anti-nutrients (tannins, phytate, oxalate, and gossypol) are also a limiting factor in the utilization of pigeon pea. Furthermore, Pigeon peas that are native to Africa are largely creamy or white with relatively low anti-nutritional factors (Damaris, 2007). Green pigeon pea seeds are considered superior to dry splits in nutrition. They have a higher crude fibre, fat and protein digestibility. The green peas are better in phosphorus by 28.2%, potassium by 17.2%, zinc by 48.3%, copper by 20.9%, and iron by 14.7% than dried pigeon peas (Saxena, 2010).

2.11 Health Benefit of Pigeon Pea

Saxena, (2010) reported some of the health benefits of pigeon pea where it is used in treatment of swelling of internal organs. In some parts of Nigeria, especially in the eastern states, pigeon pea is used for treating measles (Enwere, 1998). In India, it has been applied to tooth ache, sore gums, child delivery, and dysentery (Enwere, 1998). Furthermore, it was reported that Pigeon pea help expel bladder stones; with ability to alleviate headache and vertigo (Saxena, 2010). Similarly, in Argentina the leaf decoction is prized for genital and other skin irritations, especially in females. *Cajanus cajan* in many ways are used for bronchitis, coughs, jaundice and pneumonia (Enwere, 1998). The dried roots have been used as an alexeritic, antihelminthic, expectorant and sedative (Enwere, 1998). Also, fresh seeds have been reported to help incontinence of urine in males, which could be linked to liver and kidney ailments (Enwere, 1998).

2.12 Cooking Quality of Pigeon Pea

Pigeon peas are invariably consumed after cooking and dietary minerals such as calcium, phosphorus, mmagnesium, iron, sulphur and potassium; and water soluble vitamins (thiamine, riboflavin, and niacin) are present in large amount (Saxena, 2010). Consumers always prefer a *Cajanus Cajan* that cooks fast and produces more volume upon cooking with high consistency and flavor (Saxena, 2000). Cooking time of Pigeon pea is independent of taste and flavor (Saxena, 2000). Studies on various physico-chemical properties revealed that fast cooking of *Cajanus Cajan* was associated with large seed size, high solid dispersal, more water absorption and high nitrogen solubility (Singh *et al*., 1990). Thus, Cooking of pigeon pea improved the bio-availability of nutrients and at the same time destroyed some anti-nutritional factors (Singh *et al*., 1990). Similarly, cooking of pigeon pea seed after germination is associated with the improvements of starch digestibility (Saxena, 2010) but decrease the level of oligosaccharides. The fermentation of seeds helps in reducing inhibitory activity of digestive enzymes (Saxena, 2010). Saxena (2000) reported that thiamine and riboflavin were destroyed by heat but niacin content was unaltered during boiling, pressure cooking, and roasting of pigeon pea seeds. Furthermore, the concentration of lysine and methionine decreased on roasting but the availability of lysine and methionine improves on boiling and pressure-cooking (Saxena, 2010).

2.13 Processing and Utilization of Pigeon Pea

Pigeon pea is among the lesser known and underutilized legumes in Nigeria. However, it is believed that under-utilization could be due to limited information on its nutritional potential (Eneche, 2009). The local farmers consume it during the period of food scarcity when other popular agricultural products are scarce and expensive (Elegbede, 1998). Pigeon pea therefore belongs to the first category of lesser known and underutilized legumes just as Bambara groundnut and yam beans (Anuonye *et al*., 2012). Pigeon pea is an important protein food in many tropical areas (Elegbede, 1998). In Africa and Indonesia, the mature seeds are usually soaked for several hours before being pounded and fried or steamed. The soaked seeds are processed into porridge and eaten often in the form of a puree called 'tempeh, (Buckle and Iskandar, 1991; Singh, 1991). The immature peas and their pods are sometimes eaten as green vegetable normally prepared as any green bean. This is the most flavorful form of pigeon pea but they are often unavailable (Singh, 1991). The dried peas are more widely used and have advantage of being stored for a long period of time (Singh, 1991). In India, they are split and cooked to a paste which is then highly seasoned with onion, chilly and ginger. (Singh, 1991). Whole dried pigeon peas can be soaked overnight and then boiled in plenty of water. The long cooking time which is necessary for the production tend to exhaust the flavour of any seasonings cooked with them, so it is a good idea to reserve some seasonings to add towards the end of the cooking time (Singh, 1991; Vaidehi, 1991). In Nigeria, pigeon peas are consumed when the beans are green as vegetable or as beans when dried and mature (Ene-Obong and Obizoba, 1995).

2.14 Complementary Foods from Cereal-Legume Blends

Beyond the age of four to six months, complementary foods are required to supplement breast milk in infants. If the nutritional needs of the child are not met, serious consequences follow for growth, resistance to diseases, intellectual development and survival. Hence, it is the most critical period in life of infants (Charles, 2008). Traditional complementary foods in Africa are mostly made from cereals, starchy roots and tubers that provide mainly carbohydrate and low in protein quality (Charles, 2008). Such foods are the leading cause of protein energy malnutrition in infants and preschool children in Africa (Anuonye *et al*., 2012). Although nutritious and safe complementary foods produced by food multinationals are available in developing countries, they are far too expensive for most families. The economic situation in these countries necessitates the adoption of simple, inexpensive processing techniques (like extrusion cooking method) that result in quality improvement which could be carried out at household and community levels for the production of nutritious, safe and affordable complementary foods (Anuonye *et al*., 2012). The principle of complementing cereals with legumes has been used in the production of high protein-energy complementary foods using locally available food crops. Cereals are limiting in some essential amino acids, notably lysine and tryptophan associated with low protein content (Charles, 2008). The protein quality of cereals can be improved by supplementing with locally available legumes that are high in lysine content (Charles, 2008). Using locally available cereals and legumes, community-based complementary food production has proven successful in many African countries (Charles, 2008). Thus, “Wean mix”, a complementary food developed by the Nutrition Division of the Ministry of Health was introduced on a large scale in the country (Charles, 2008).

2.15 Extrusion Cooking Technology

Extrusion technology has contributed greatly in the food industries towards shaping and deriving ready to eat products (Fellows, 2009). The use of extrusion in the food processing has increased its popularity due to its versatility, cost-effectiveness, environmental friendliness and better product output (Guy, 2001c). The principle of the extrusion process involves the loading of raw materials in the feeding hopper where the screw conveys the raw materials. When the raw materials pass down the barrel, the volume is reduced and the food is compressed under pressure into a semi-solid, plasticized mass. The selection of right extruder for the production of ready to eat (RTE) or cereal snacks depends on the nature of raw materials used, bulk density and type of product to be produced (Fellows, 2009).

2.16 Advantages of Extrusion Cooking

(i) Product quality: extrusion cooking requires high temperatures application for a short period of time and this treatment therefore aids in retaining many of the sensitive components (Fellows, 2000). It also reduces microbial contamination and inactivates enzymes (Roland and Stanley, 2011).

(ii) Versatility: A wide variety of products are possible by changing the ingredients, the operating conditions of the extruder and the shape of the dies.

(iii) Reduced Costs: Extrusion has lower processing costs and higher productivity than other cooking or forming processes. Some traditional processes including manufacture of cornflakes and frankfurters are more efficient and cheaper when replaced by extrusion (Roland and Stanley, 2011).

(iv) No process effluents: Extrusion is a low moisture process that does not produce process effluents. This eliminates water treatment costs and does not create problems of environmental pollution (Roland and Stanley, 2011).

(V) High production rates and automated production: Extruders operate continuously and have high throughputs. For example, production rates of higher output for snack foods, low density cereals and dry expanded pet foods are possible (Roland and Stanley, 2011).

2.17 Types of Extrusion Cooking Method

The most widely used extruders are basically classified into single and twin screw extruders. The single screw extruders (Plate 2.2) are classified into four i.e low shear forming extruder, low shear cooking, medium shear cooking and high shear cooking single screw extruders

(Riaz, 2005). The size and shape of the extrudates and efficiency of the extruder performance are interdependent on the operational parameters such as temperature, pressure and screw speed (Fellows, 2009). The residence time in the extrusion plays an important role in the performance of the product which can be controlled by screw speed. With respect to the twin screw extruders, they are classified based on degree of co-rotation and the degree of interconnection between the two screws (Fellows, 2009). Similarly, the twin screw extruders are also classified into four i.e. Co-rotating intermeshing, Co-rotating non-intermeshing, Counter-rotating intermeshing and lastly, Counter-rotating non-intermeshing twin-screw extruders (Riaz, 2005). The advantage of using twin screw extruders is versatility to process wide range of products like tortillas, cereal snacks, extruded corn snacks, and multigrain snacks (Riaz, 2005). Due to high capital and maintenance costs, single screw extruders are considered to be cost-effective when compared with twin screw extruders.

Plate 2.2: Single screw extruder used for preparation of Extruded products (Beladhadi *et al.*, 2015).

2.18 Processing Factors Affecting both the Extruder and Extruded Products

The processing parameters play an important role in determining the quality output of the extruded snacks (Chessari and Sellahewa, 2001). The process of controlling the product depends on various primary and secondary extrusion process parameters. The primary process parameters include feed rate, screw speed, barrel temperature, water content, feed formulation, screw and die configuration. The secondary process parameters include die temperature, pressure and torque (Chessari and Sellahewa, 2001). The pre-conditioning treatment of the raw materials using of hot water or steam for about 4-5 minutes helps in gelatinization of starch and protein denaturation of the raw materials during the extrusion processing (Bailey *et al*., 1995). Durge *et al*. (2013) also reported that extrusion cooking could be used to study the stability of beetroot as a pre-extrusion coloring agent for rice flour. During this process, the parameters that were taken into account were water content, screw speed and die temperature.

2.19 Functional and Chemical Changes during Extrusion

The changes occurring during the extrusion cooking plays a major role in determining the shape and crispness of the extrudates especially for cereal based snacks (Guy, 2001b). One of the important phenomena during the process of extrusion is gelatinization. The process of starch gelatinization helps in gas-holding capacities that result in expansion of extrudates (Guy, 2001b). During the starch gelatinization, breakage of intermolecular hydrogen bonding results in the increase in the absorption of water associated with swelling of starch granules (Fellows, 2009). As the temperature gradually increases, starch molecules are gelatinized which result in the formation of viscous fluid melt. The fluid melt forms the outer coating for the foam bubbles that contain superheated water vapour. During the exit of materials from the extruder die, there is sudden drop in pressure which results in expansion of bubbles by loss of moisture due evaporation (Fellows, 2009). These physical changes during the extrusion process increases the viscosity of material followed by formation of glassy state relative to the degree of vaporization of water in the extrudates structure (Guy, 2001b). The expansion of the extrudates greatly depends on the content of amylose and amylopectin present in the starch granules (Guy, 2001b). Higher content of amylose in the starch results in low viscous fluid melt thereby resulting in greater expansion of foods during the extrusion processing. With respect to the extrusion parameters, processing temperature, water content in the feed and shearing rate are important in the expansion of extrudates during extrusion processing (Guy, 2001b).

Similarly, El-samahy *et al*. (2007) reported a positive correlation between expansion and starch level in extruded products. Starch gelatinization lead to expansion when gelatinization occurs. However, low screw speed and high moisture content of the process causes minimal expansion from starch swelling. The low expansion index associated low starch-high protein content could be attributed to protein swelling and collapsing due its visco elastic property. Unlike bulk density, the average bulk density of navy bean is significantly higher than those of extruded bean analogs. Bean analog extrudates was observed to be significantly denser after drying because the products had lost some moisture.

2.20 Effect of Extrusion on the Nutritional Properties of Extruded Products

The bioavailability of nutrients during the processing of foods is always considered important for obtaining any nutritional products (Singh *et al*., 2007). The advantages of extrusion cooking with respect to the nutritional content of the final product are the inactivation of antinutrients, destruction of aflatoxins and increasing the digestibility of fiber (Singh *et al*., 2007; Saalia and Phillips, 2011). Areas (1992); Kitabatake and Doi (1992) reported that denaturation of proteins during the extrusion processing caused inactivation of antinutrients (such as lectin and trypsin inhibitors) which results in the increased protein digestibility. During the process, disulphide bonds break and reunite, while the high molecular proteins dissociate into smaller subunits (Guy, 2001d). (Srihara and Alexander, 1984; Hakansson *et al*., 1987; Colonna *et al*., 1989; Areas, 1992). Similarly, Chávez-Jáuregui *et al*. (2000) and Repo-Carrasco *et al*. (2009) reported that there was better retention of protein content during the extrusion processing on amaranth. Texturization of the protein-based foods was affected due to the effect of extrusion cooking thereby improving taste of the extrudates. (Cheftel *et al*., 1992). According to Areas (1992) the electrostatic interactions and disulphide bonding could have an important role in texturization of foods during the extrusion process. Retention of lysine in the breakfast cereals is considered most important since it is the limiting amino acid amongst most cereal snacks.

The lysine content in the extruded soy potato blends were around 68-100 % depending on the content of the feed (Iwe *et al*., 2004). Similarly, there was increase in the availability of lysine during the extrusion processing due to increase in the screw speed and the feeding rate

(Iwe *et al*., 2004). However, increase in processing temperature, die diameter and water content during the extrusion processing decreased the lysine availability (Noguchi *et al*., 1982; Pham and Del Rosario, 1984). During the extrusion cooking of amaranth, no significant effect on lysine availability was reported (6-7 g /100g) (Chávez-Jáuregui *et al*., 2000). Thus, lower water content of the feed initiates non-enzymatic browning reaction termed as Maillard reaction. Noguchi *et al*. (1982) found decreased availability of lysine during the Maillard reaction at high extrusion processing (≥180 °C) and lower water content (≤15 %) of the feed. (Singh *et al*., 2007). The effects of extrusion on fat were also studied. Raw materials containing less than 5 % total fat content have better retention of lipids when compared with raw materials of higher fat content (Nierle *et al*., 1980). The addition of antioxidants (phenolics) also reduced the effect of lipid oxidation in the extrudates which result in the better retention of nutritional properties (Camire *et al*., 2005). The process of extrusion cooking at higher temperature enhanced the lipid oxidation in extruded corn based snacks (Rao and Artz, 1989; Martin *et al*., 1993; Zadernowski *et al*., 1997).

Furthermore, increase in the total dietary fiber content of the extruded barley flours was determined with respect to content of soluble dietary fiber. Effect of extrusion on the dietary fiber content led to the transformation of insoluble dietary fiber to the soluble dietary form in addition to the formation of resistant starch and enzyme resistant glucans through the process of transglycosidation (Repo-Carrasco *et al*., 2009). The increase in the soluble dietary fiber content of amaranth varieties during the process of extrusion was reported to be due to shear stress and high processing temperatures which caused breakage of chemical bond by forming cluster of tiny particles which increase soluble dietary fiber content (Gualberto *et al*., 1997).

Vitamin losses were also reported in the foods that were produced through extrusion. α-tocopherol content in the extruded peas decreased with an increase in the extrusion temperature (Grela *et al*., 1999). Also, loss of riboflavin was reported due to increase in water content of the feed and screw speed (Harper, 1988). Milder extrusion temperatures (150 °C) and short residence time resulted in better retention of heat-sensitive vitamins (vitamin B_1 and B_2) (Singh *et al*., 2007). Athar *et al*. (2006) reported that there was 44-62 % retention of B vitamins in snacks during the extrusion processing of cereals with higher stability of riboflavin (vitamin B_2) and niacin (vitamin B_3). Absorption of minerals can be enhanced by extrusion process (Alonso *et al*., 2001). by increasing the mineral availability in the extrudates.

2.21 Effect of Extrusion on the Antinutritional Properties of Extruded Snacks

Extrusion Cooking Method has helped in the complete elimination of trypsin inhibitors in the extrudates (El-Hady and Habiba, 2003). The content of trypsin inhibitors in the extrudates of beans and peas were reduced to negligible amounts during the extrusion processing. The inactivation of lectins and trypsin inhibitors increased with the increase in the processing temperature and water content of the raw materials. El-Hady and Habiba (2003) also reported that the soaking of beans and peas for a period of 16 hours followed by extrusion processing resulted in better elimination of antinutrients in the extrudates. Extrusion of cereals was also studied extensively (Kaur *et al*., 2013). The extrusion of wheat, rice and barley at 140 °C and water content (20 %) resulted in more than 50% reduction in the content of phytates, trypsin inhibitors and oxalates in the extruded cereal snacks. Camire (2001) also summarized the effect of extrusion on antinutritional factors against various extrusion parameters. Elimination of protease inhibitors can be successfully achieved by the process of extrusion at higher temperatures while the complete inhibition of gossypol can be achieved by increasing the water content of the feed during the extrusion processing (Camire, 2001).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Material

3.1.1 Sample collection

Paddy Rice (White colour) was collected from National Cereal Research Institute Badeggi, Niger State; and Pigeon pea (Brown colour) was purchased from Samaru Market, Zaria, Kaduna State. Thereafter, it was taken to Herbarium in Botany Department, Faculty of Life Sciences, Ahmadu Bello University Zaria, Kaduna State for identification and authentication with a Voucher Number given as 2409.

3.1.2 Chemicals

Table 3.1: Chemicals/Reagents Used During Analysis of Instant Porridge

Chemicals	Grade	Manufacturer
Sodium Hydroxide (NaOH)	British Drug House	England
Hydrochloric Acid (HCl)	British Drug House	England
Sulphuric Acid (H_2SO_4)	Mayer and Baker	England
Perchloric Acid ($HClO_4$)	Mayer and Baker	England

3.1.3 Equipment

Table 3.2: Equipment Used for the Production of Instant Porridge

Equipment	Model	Manufacturer
Attrition Mill	Retsch, RM 100 Model	England
Amino Acid Analyzer	Beckman System 6300 Model	Germany
Blender	Qlink, LB040D31	Japan
Dehuller	Statake Tokyo M_3 Rice Dehuller	Japan
Extruder	Duisburg, DCE-330 Model	Germany
Weighing Balance	Mettler, Toledo, JS703C/A Model	England
Muffule Furnance	Carbolite, Bamford, S302AU	England
Flame Photometer	Gallenkamp, S320	England
Heating Mantle	Gallenkamp, B HL-035	England
Water Bath	Cambridge, JB5,6306303005	England

3.2 Methods

3.2.1 Processing of Samples

Two kilograms of paddy rice was cleaned by winnowing. The kernels were dehulled using a rice dehuller (Satake Tokyo $M_{3,}$ Rice Dehuller, Japan). The dried grains were milled into flour and sieved to pass through a 2 mm mesh sieve and packaged for extrusion. Pigeon pea seeds (2 kg) were cleaned manually from all the foreign materials and soaked in cold water for 8 hours, followed by continuous washing to remove the seed coat. Thereafter, the water was drained off and the seeds were dried until constant weight was obtained. The dried seeds were milled using Attrition mill (Galenkamp, England) and sieved to pass through a 2mm mesh sieve. The sieved flour was then packaged in polyethylene bag until require for extrusion, according to Anuonye (2012).

3.2.2 Formulation of the flour blend

Rice and pigeon pea flours were blend at different ratio based on experimental design (Table 3.4). After which the moisture content of the mixture was measured by hot air oven method to set as the initial moisture content of the blends (M_1). The blended flour samples were conditioned to appropriate moisture content (20-30 w/w) by spraying with a calculated amount of water (Table 3.4) and mixing continuously in a blender (Q Link, LB040D31). The flour samples were put in closed containers and stored overnight. The amount of water to be added was calculated according to Wilmot (1998).

$$W_w = W_d \times \frac{(M_2 - M_1)}{(1 - M_1)(1 - M_2)} \quad \text{.....} \quad (3.1)$$

Where W_w is the amount of water to be added, W_d is the dry weight of the raw flour, M_1 is initial moisture content and M_2 is the desired moisture content. Similarly, a small scale laboratory single screw extruder (Duisburg DCE – 330 Model, Germany) with three zones (feeding, cooking and die zones) equipped with a screw feeder and a 3 mm die was used to extrude the different formulations.

The extrusion process involves the loading of raw materials in the feeding hopper where the screw conveys the raw materials. When the raw materials pass down the barrel, the volume is reduced and the food is compressed under pressure into a semi-solid, plasticized mass via the die nozzle. After which extruded samples were collected and dried overnight in an oven at 60 ^{o}C. The dried samples were then stored in a desiccator for further analysis.

3.2.3 Extrusion Experiment by Central Composite Design (FCCD)

CCD was carried out to determine the most important factors affecting the process. In this study, independent variables considered were screw speed (150-250 rpm), feed moisture content (20-30 w/w) and feed blend composition (10-30 w/w) which were prepared according to design matrix of FCCD using Design-Expert software 6.0.8 (Stat Ease Inc., Minneapolis, USA). Thus, 20 experiments including six replicated center points where the independent variables were considered at three different levels, low (−1), medium (0) and high (+1) were shown in Table 3.3.

Table 3.3: Independent Variables, Levels and the Actual Values Used for FCCD

	Actual level		
Independent variables	-1	0	+1
Screw speed (rpm)	150	200	250
Feed moisture content (%)	20	25	30
Feed blend composition (%)	10	20	30

–1= Low Level

0 = Medium Level

+1 = High Level

Table 3.4: Independent Variables, Levels and the Actual Values to be Used for Face Central Composite Design

	Independent variables in their coded and actual forms			
Experimental Runs	Screw Speed (%)	Feed Moisture Content (%)	Feed Blend Composition (%)	Responses
1	150	20	10	
2	250	20	10	
3	150	30	10	
4	250	30	10	
5	150	20	30	
6	250	20	30	
7	150	30	30	
8	250	30	30	
9	150	25	20	
10	250	25	20	
11	200	20	20	
12	200	30	20	
13	200	25	10	
14	200	25	30	
15	200	25	20	
16	200	25	20	
17	200	25	20	
18	200	25	20	
19	200	25	20	
20	200	25	20	

-1= Low level, +1= High level, 0= Medium.

3.3 Determination of Functional Properties

3.3.1 Bulk density

The method of Onwuka, (2005) was adopted where 10 g of each sample was measured into a clean 100 ml graduated measuring cylinder and the bottom of the cylinder was tapped repeatedly on a padded table until no further reduction was seen in volume. All measurements were carried out in triplicate and the average volume was recorded as the packed volume. The bulk density was calculated based on the general formula:

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of Sample (g)}}{\text{Volume occupied by the sample (ml)}} \quad \text{.............................(3.2)}$$

3.3.2 Expansion index (EI)

Expansion index was determined by dividing the cross sectional area of the extrudate by the cross-sectional area of the die nozzle as adopted from the work of (Alvarez–Martinez *et al*., 1988). Six lengths of extrudates (approximately 120 mm) were selected at random during collection of each of the extruded samples. The diameter of the extrudate was measured at 10 different positions along the length of each of the six samples, using a vernier caliper. Expansion index (EI) was calculated using the mean of the measured diameters.

$$\text{Expansion index} = \frac{\text{Diameter of the extrudate}}{\text{Diameter of the nozzle}} \quad \text{.......................................(3.3)}$$

3.3.3 Water absorption index (WAI)

The water absorption index was determined using the method described by Qing-Bo *et al*., (2005). The ground extrudates was suspended in water at a temperature of 30°C for 30 min; it was stirred gently during this period, followed by centrifugation at 3000 × *g* for 15 min. The supernatant was decanted into an evaporating dish. The water absorption index was considered as the weight of gel obtained after removal of the supernatant through a strainer per unit weight of original dry solids.

$$\text{Water absorption index} = \frac{\text{Weight of wet sediment}}{\text{Weight of dry sample}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3.3)$$

Where: W_1 = weight of container or empty dish (g)

W_2 = weight of container + sample before addition of H_2O (g)

W_3 = weight of container + sample after addition of H_2O (g)

3.4 Proximate Composition

3.4.1 Determination of moisture content

Watch glass was washed and dried in an oven at 105 ^oC, and the container was cooled and weighed empty. Two grams of each sample was weighed into the watch glass. The whole content was dried in an air circulated oven at 105 ^oC to a constant weight. The watch glass as well as its contents was cooled in the dessicator and reweighed as described by AOAC (2000). The percentage moisture content of extrudates was calculated using the equations: Furthermore, the same procedure was repeated for other samples

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_1 - W_2} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.5)$$

Where: W_1 = weight of crucibles (g)

W_2 = weight of crucibles + sample before drying (g)

W_3= weight of crucibles + sample after drying (g)

3.4.2 Ash content determination

Determination of ash content was carried out according to the method described by AOAC (2000). A crucible was preheated in a muffle furnace at about 550 ^{o}C for 3 hours. Each crucible was cooled in a dessicator and weighed. Approximately 1 g of each sample was weighed into different crucibles. The crucibles and their contents were then transferred into the muffle furnace at 550 ^{o}C and allowed to stand for 5 hours. The weight of the crucibles was taken and recorded. Percentage ash content was calculated using the formula:

$$\text{Ash content (\%)} = \frac{W_2 - W_3}{W_1 - W_2} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.6)$$

Where: W_1 = weight of crucibles (g)

W_2 = weight of crucibles + sample before drying (g)

W_3= weight of crucibles + sample after drying (g)

3.4.3 Determination of fat contents

Crude fat content was determined by AOAC, 2000 using Soxhlet extraction method (AOAC, 2000). Exactly 2.00 g of each sample were weighed and poured into an extraction thimble and plugged with free fat cotton wool. Each thimble was placed into the Soxhlet extractor.

Exactly 150 ml of the petroleum ether was poured into a dry 250 ml quick fit flask fitted with the extractor and condenser units, samples were refluxed for 8 hours. After extraction, the crude fat mixture was at a low heat and the petroleum ether evaporated to near dryness flask containing crude fat extracted were further dried in the oven at 105 ^{o}C for 30 min, cooled in a desiccator and weighed. The percentage crude fat was determined using the formula:

$$\text{Crude lipid (\%)} = \frac{\text{Weight of lipid extracted}}{\text{Weight of the dry sample}} \times 100 \quad \text{……………………………...(3.7)}$$

3.4.4 Determination of crude fiber

The percentage crude fibre was determined by AOAC (2000). Exactly 2.00 g of the extrudates were transferred into a 500 ml conical flask followed by 200 ml of boiled 1.25 % H_2SO_4 solution. The mixture was boiled for 30 minutes under reflux. The digest was filtered through a Whatman filter paper number 54. The residue was washed with boiling water until the washing was free from acid. The acid free residue was quantitatively transferred into the refluxing flask followed by exactly 200 ml of 1.25 % sodium hydroxide solution and refluxed for 30 minutes. The digest was filtered, washed with boiling water, then alcohol and lastly with diethyl ether before being dried at 100 ^{o}C for one hour. The dried residue was transferred into a porcelain crucible and incinerated for one hour at 400 – 500 ^{o}C using a muffle furnace. The crucibles were removed from the furnace and let to cool in the desiccator and immediately transferred and weighed. Percentage fibre was calculated using the following equation:

$$\text{Crude fibre content (\%)} = \frac{W_1 - W_2}{W} \times 100 \quad \text{………………………………………..(3.8)}$$

Where: W_1 = weight of crucibles with dried residue before ashing (g)

W_2 = weight of residue after ashing (g)

W= weight of sample (g)

3.4.5 Determination of nitrogen content and crude protein

Crude protein determination was determined by Kjedhal method (AOAC, 2000). Two grams (2g) of each sample was weighed into 100 ml Kjedhal flask. One gram of the mixed catalyst ($CuSO_4$ and K_2SO_4 in a ratio of 8:1) and 15 ml of concentrated sulphuric acid were added. The flask was placed on a Kjedhal digestion rack and heated until a clear solution was obtained. At the end of the digestion, the flask was cooled and the sample was transferred into a 100 ml volumetric flask and made up to the mark with distilled water. Ten milliliters of the digest were pipetted into semi micro nitrogen steel tube, 10 ml of 40 % NaOH solution was then added into a 100 ml conical flask containing 10 ml of 4% boric acid using methyl blue indicator until the colour changed from pink to green. Exactly 30 ml of the sample volume was collected. The content of the conical flask was titrated with 0.1 N HCl. The end point was indicated by a colour change from green to pink and the volume (v) of the acid for each distillate was noted. Percentage nitrogen per sample was calculated using the formula:

$$\text{Nitrogen content (\%)} = \frac{\text{(Titre - Blank) ml x 0.014077)}}{\text{Weight of the sample (g)}} \times 100 \qquad \text{………………………...(3.9)}$$

The crude protein was calculated as % Protein = 6.25 × % nitrogen.

3.4.6 Determination of carbohydrate content

The percentage carbohydrate was obtained by difference thus;

NFE (%) = 100 - (% ash + % crude fibre + % crude fat + % moisture + % crude protein).

Where,

NFE= Nitrogen Free Extract

3.5 Mineral Analysis

Zinc (Zn), Iron (Fe), Calcium (Ca), Sodium (Na), Potassium (K) and Magnesium (Mg) were determined by Atomic Absorption Spectrophotometry (AAS); according to the method of AOAC (2003). Exactly 1.0 g of each sample was transferred into the digesting glass tube. Twelve milliliters (12 ml) of HNO_3 was added to the sample and the mixture was kept overnight at room temperature. Then 4.0ml of perchloric acid ($HClO_4$) was added to this mixture and kept in the fume hood for digestion. The temperature was increased gradually starting from 50 ^{o}C – 300 ^{o}C. The digestion was completed in about 80 minutes as indicated by the appearance of white fumes. The mixture was left to cool down and the contents of the tubes were transferred into 100ml volumetric flask and the volume of the contents was made to 100 ml with distilled water. The wet digested solution was transferred to plastic bottles labeled accurately and stored for mineral determination. Atomic Absorption Flame Emission Spectrophotometer was used for the samples analysis. The dilution factor for all minerals was added to make the volume up to 100 ml.

The concentration of minerals was determined using the formula.

$$Mw = \frac{(\text{Absorbence value x dry weight} \times D)}{\text{Weight of the sample}} \times 100 \quad \text{.................................}(3.10)$$

Where Mw = Concentration of minerals, D = Dilution factor

3.6 Amino Acid Analysis

The method of Sotelo *et al.* (1994) was used in determining the amino acid content of the extrudates. One gram of each sample was dissolved in 20 ml of 6N HCl in a hydrolysis tube and kept for 22 hours under a nitrogen atmosphere. The acid was evaporated using a rotatory evaporator and the residue was washed three times with distilled water. The extracted sample was dissolved in 1ml acetate buffer of pH 3.1. After dilution, the hydrolysate was transferred into a Beckman system (Model 6300) high performance amino acid analyzer.

3.6.1 Defatting of sample using soxhlet extraction apparatus

one gram of the defatted sample was weighed into glass ampoule. About 7 ml of 6 N HCl was added and oxygen was expelled by passing nitrogen into the ampoule (this is to avoid possible oxidation of some amino acids during hydrolysis such as methionine and cystine). The filtrate was then evaporated to dryness using rotary evaporator.

3.6.2 Loading of the hydrolysate into the TSM analyzer

About 5 to 10 microlitre of the extruded sample was loaded into 60 microlitre TSM analyzer. This was dispensed into the cartridge of the analyzer. The analyzer was designed to separate and analyze free acidic, neutral and basic amino acids of the hydrolysate. Then, the residue was dissolved in 5ml of acetate buffer (pH 2.0) and stored in plastic bottles, after which an integrator was attached to analyzer.

3.6.3 Method of calculating amino acid values from the chromatogram peaks

The method of calculating amino acid value from the chromatogram peak was based on the measurement of net heights of each peak produced by the chart record of the TSM. The half-height of the peak on the chart was found and width of this peak was accurately measured and recorded. Approximate area of each peak was then obtained by multiplying the height with width at half height.

The non-leucine equivalent (NE) for each amino acid in the standard mixture was calculated using the formula:

$$\text{NEST} = \frac{(\text{Area of non-leucine peak})}{\text{Area of each amino acid}} \quad \text{……………………………..………………..(3.11)}$$

A constant, S was calculated for each amino acid in the standard mixture:

S std = NEST × Mol weight × µm AAstd

Finally, the amount of each amino acid present in the samples was calculated g/100g protein using the following formular:

Concentration (g/100g) =NH_2 × S × C

$$C = \frac{\text{Dilution} \times 16}{\text{Sample} \times \text{wt (g)} \times \text{N\%} \times 10 \times \text{Vol loaded} \div \text{NH} \times \text{W (leu)}} \quad \text{……………………...(3.12)}$$

For this extruded products analysis C for basic amino acid =1 × 10^{-3}

For acidic amino acid =2 × 10^{-3} Volume loaded for basic amino acid =10µl

Volume loaded for acidic amino acid =5µl Weight hydrolyzed =0.4032

Nest =Non-leucine standard   Std =Standard NH =Net height

NH/2 =Half Net height   µm =Micromoles in standard sample

Concentration of hydrolysates Mol. Weight =Molecular weight of sample

3.7 Sensory Evaluation

Sensory evaluation of formulated instant porridge from rice-pigeon pea blend was conducted using twenty (20) semi- trained panelists. Samples were presented in four coded white plastic cups. The order of presentation of the sample to the panelists was randomized. Clean tap water was provided for the panelists to rinse mouth in between evaluation. The panelists were familiar with the samples and they were asked to indicate their opinion on four sensory attributes, namely the colour, flavor, texture and the overall acceptability using Hedonic scale rating of 9 = liked extremely to 1 = disliked extremely. Acceptability scores using the mean of the observations were recorded.

3.8 Statistical Analysis

Data collected were expressed as mean ± standard deviation. Analysis of Variance (ANOVA) using Duncan Multiple Range were carried out to determine the differences among the samples with significant differences accepted at $p<0.05$. A quadratic model was also developed so as to define the response (functional properties) in terms of the selected independent variables. Coefficient of determination R^2 and the adjusted R^2 as well as the derived p-values were used to evaluate the model fitness.

CHAPTER FOUR

4.0 RESULTS

4.1 Effect of Extrusion Parameters on the Functional Properties of Rice-Pigeon Pea Blend

The results of functional properties of instant porridge produced from rice-pigeon pea blend were indicated in Table 4.1. Among the selected functional properties, expansion index of the extrudates reaches its maximum in run 12 (9.56) and the lowest value was obtained in run 5 (2.13). The bulk density of rice-pigeon pea blend was found to be highest in run 5 and 6 with a value of 0.11 g/ml due to increase in addition of pigeon-pea composition and the lowest value was observed in run 12 (0.05 g/ml) when screw speed was higher. Similarly, Table 4.1 also indicated the highest value for water absorption index of 6.26 (run 1) when lower screw speed was observed and the lowest value of 3.96 (run 5) was obtained due to higher screw speed.

Table 4.1: Central Composite Design of Rice-Pigeon Pea Flour Blend Based on three Independent Variables Using Functional Properties as the Response

Experimental Runs	Screw Speed (rpm)	Feed Moisture Content (%)	Feed Bleed Composition (%)	Expansion Index	Bulk Density (g/ml)	Water absorption Capacity (g/g)
1	150	20	10	4.26	0.07	6.26
2	250	20	10	6.26	0.09	5.85
3	150	30	10	4.48	0.06	6.12
4	250	30	10	5.23	0.08	4.87
5	150	20	30	2.13	0.11	3.96
6	250	20	30	2.88	0.11	5.72
7	150	30	30	7.11	0.06	5.58
8	250	30	30	8.11	0.06	5.77
9	150	25	20	6.01	0.07	5.37
10	250	25	20	7.51	0.09	5.48
11	200	20	20	6.46	0.06	5.10
12	200	30	20	9.56	0.05	5.55
13	200	25	10	5.76	0.06	5.69
14	200	25	30	4.76	0.07	5.06
15	200	25	20	7.12	0.07	4.94
16	200	25	20	6.12	0.07	4.64
17	200	25	20	7.37	0.06	5.09
18	200	25	20	7.37	0.06	5.09
19	200	25	20	7.37	0.06	5.09
20	200	25	20	7.37	0.06	5.09

Note: -1= (Low level), +1= (High level), 0= (Medium)

4.2: Analysis of Variance of the Developed Quadratic Model for Rice-Pigeon Pea Flour Blend

4.2.1 Expansion index

Based on the developed mathematical model, the relationship between the expansion index as the response and the selected variables was expressed in terms of quadratic equation:

Expansion Index = $0.50 + 7.21A + 1.40B + 0.00C - 0.65A^2 + 0.83B^2 - 2.16C^2 - 0.25AB - 0.25AC + 1.50BC$ ……………………………….. (4.1)

Using the analysis of variance, f-values obtained were used to determine the fitness of the developed model as indicated in Table 4.2. The overall model has a p-value of <0.0001, which suggested that the model was significant $p<0.05$. From the responses in Table 4.2; two of the linear coefficients i.e. screw speed and feed moisture content, one each of quadratic (feed blend composition) and interaction (feed moisture content and feed blend composition) coefficients were significant at $p<0.05$. Similarly, the non-significant lack of fit was valid with a value of 0.380. In case of coefficient of determination R^2 and adjusted R^2, values of 0.9592 and 0.9224 were obtained (Table 4.2); which showed the efficacy of the model that determine the fitness of the model equation.

Similarly, R^2 is the ratio that explained the total variation and also determine the degree of fitness of a regression model (Singh *et al*., 2007; Filli *et al*., 2011). It defines the proportion of the variability in the observed response variables which is accounted by regression analysis (Filli *et al*., 2011). If the R^2 value is close to unity, the better the model fits of the actual data (Zaibunnisa *et al.*, 2009), but the lesser the value of R^2, the less relevant the model have in explaining the response variables. Zaibunnisa *et al*. (2009) suggested that R^2 value should be at least 80% to have a better fit of a regression model. The results of this study therefore showed that the model for all the responses were adequate to explain the variable response because they have satisfactory level of R^2 which is higher than 80%. Adequate precision value of 20.551 and the coefficient of variation of 8.41 were obtained.

Table 4.2: Analysis of Variance of the Developed Quadratic Model for Expansion Index

Source	Sum of Squares	Mean Square	F-Value	P-Value
Model	64.36	7.51	26.10	<0.0001*
A	2.50	2.50	9.12	0.0129*
B	19.52	19.52	71.23	<0.0001*
C	0.000	0.000	0.000	1.0000
A^2	1.18	1.18	4.31	0.0647
B^2	1.89	1.89	6.91	0.0252*
C^2	12.77	12.77	46.61	<0.0001*
AB	0.50	0.50	1.82	0.2065
AC	0.50	0.50	1.82	0.2065
BC	18.06	18.06	65.91	<0.0001*
Lack of Fit	1.56	0.31	1.33	0.38
C.V	8.41			
R^2	0.9592			
R^2 Adjust	0.9224			
Adeq Precision	20.551			

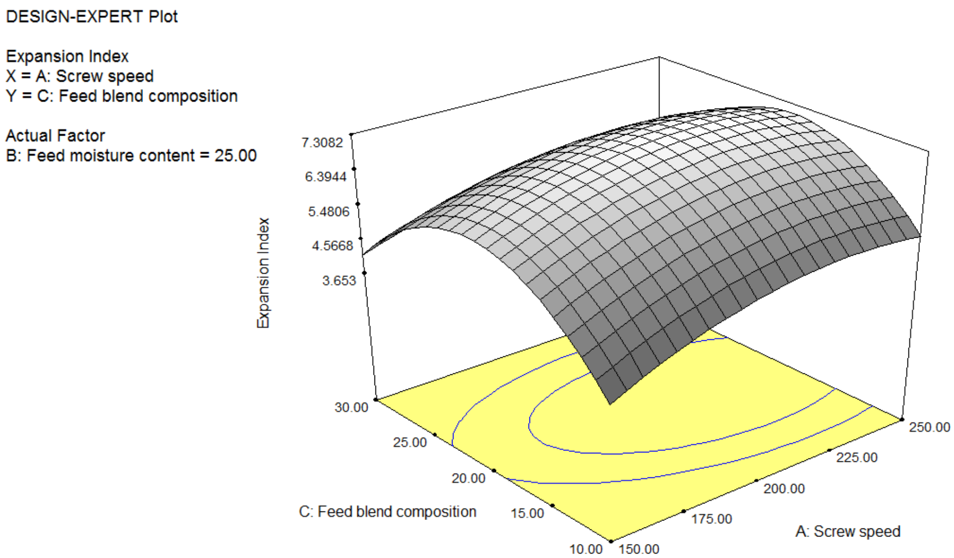
4.2.2 Three dimensional graph showing combined effects on expansion index of instant porridge from rice-pigeon pea flour blend

The relationship between independent and response variables were shown in the three dimensional graph of the response obtained by the models. The three dimensional graph was based on the regression coefficient. Similarly, Optimum values of the responses were obtained by analysing the response surface plots and the model equation generated. The three dimensional response surface plots showed the synergistic effects of the selected parameters on the expansion index of the developed pigeon-pea blend presented in Figure 4.1.

Thus, Figure 4.1a indicates the effect of feed blend composition and feed moisture content on expansion index, at fixed screw speed of 200 rpm (middle level). It can be seen that expansion index increases with increase in concentrations of both feed blend composition and feed moisture content until the optimum response was obtained. Similarly, Figure 4.1b showed the nature of expansion index on feed blend composition and screw speed. The response surface was elliptical in nature but the p-value obtained in Table 4.2, suggested that the interaction was not significant ($p>0.05$).

Residual analysis was used to validate fitness of the developed model. The variation between the actual and predicted values is termed the residual. Fig 4.2 are the graphical presentation of the relationship between the actual and predicted values of the expansion index of the instant porridge developed from rice-pigeon pea flour blend. Furthermore, the linear pattern of the graph shows that the models were close to each other which provide an accurate fit to the actual values.

(a)



(b)

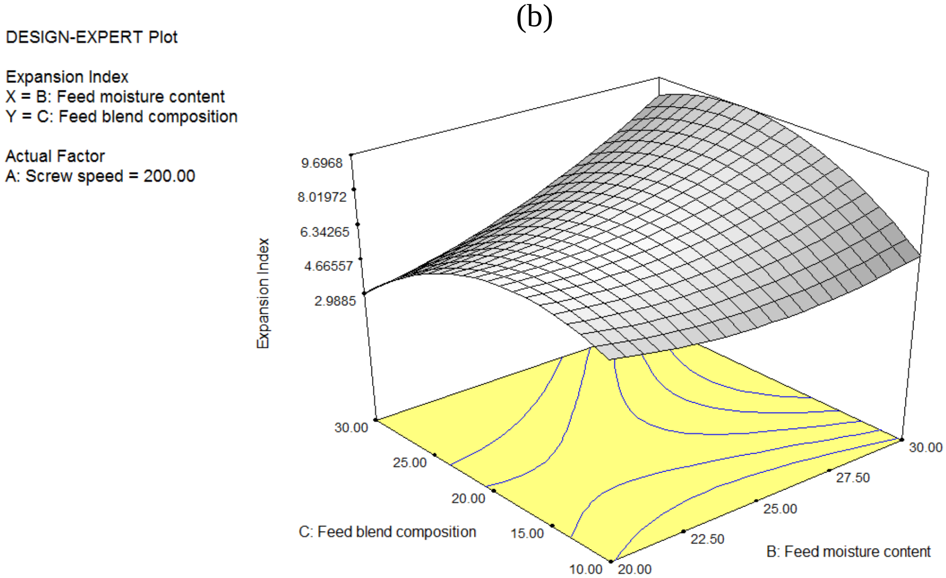


Figure 4.1: Three dimensional graph showing the combined effects of independent variable on expansion index of pigeon-pea blend.

(a) feed blend composition and screw speed (b) feed blend composition and feed moisture content (at fixed Screw Speed of 200rpm)

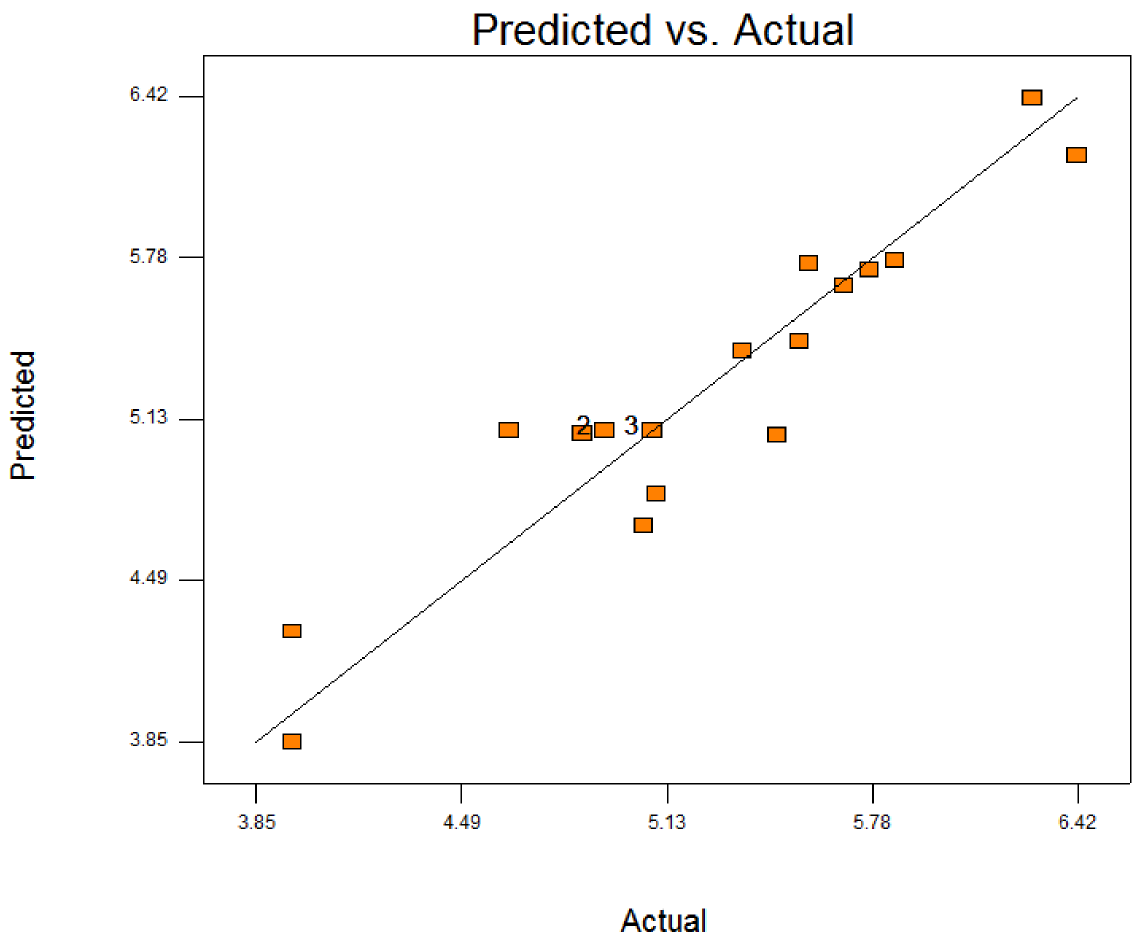


Fig 4.2: Residual graph for the actual versus predicted mean effects of processing variables on the expansion index of rice-pigeon pea flour blend.

4.2.3 Bulk density

Table 4.3 shows the analysis of variance of the developed quadratic model for Rice-Pigeon pea blends where the linear effect of the independent variables has strong influence on the bulk density at $p<0.05$. Two interaction terms (Screw speed and feed blend composition (AC), and feed moisture content and feed blend composition (BC) were also significant with p-values of 0.0478 and 0.0011, respectively. Lack of fit was not significant at $p>0.05$.

Similarly, R^2 and adjusted R^2 values were found to be 0.925 and 0.858 respectively. Adequate precision of 14.49 was found to be desirable since a value >4 was obtained. In case of CV, a value of 8.70 was obtained (Table 4.3). The relationship between the bulk density as the response and the selected variables was expressed in equation 4.2:

$$\text{Bulk Density (g/ml)} = 0.06 + 6.00A + 0.01B + 5.00C + 0.02A^2 - 6.36B^2 + 3.64C^2 + 0.00AB - 5.00AC - 0.10BC \quad \ldots\ldots\ldots\ldots \quad (4.2)$$

It can be seen from Table 4.1 that there was low bulk density (0.05g/ml) at 200 screw speed (rpm). These observations were found to be significant with p-value less than 0.05, as indicated in Table 4.3.

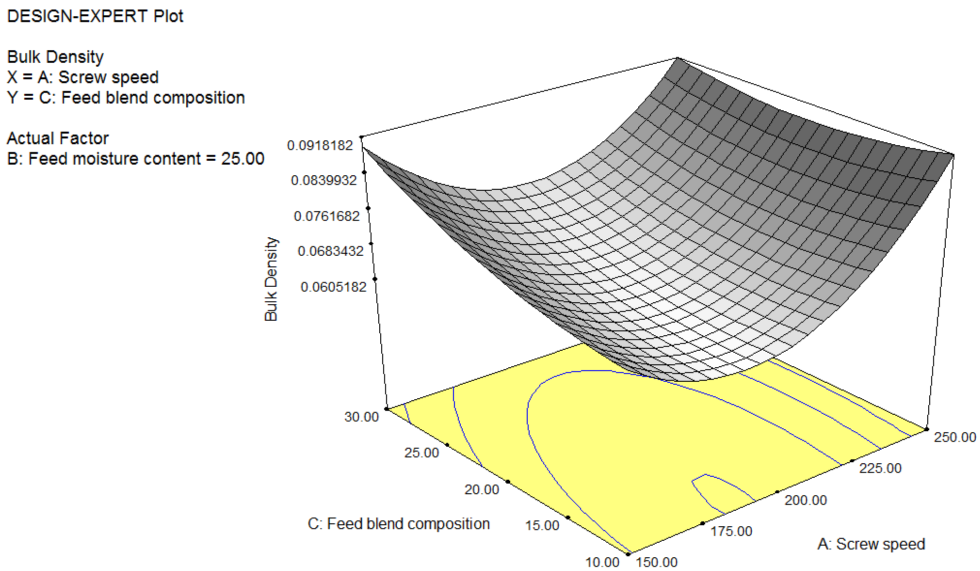
Table 4.3: Analysis of Variance of Developed Quadratic Model for Bulk Density

Source	Sum of Squares	Mean Square	F-Value	P-Value
Model	4.861	5.402	13.72	0.0002*
A	3.600	3.600	9.15	0.0128*
B	1.690	1.690	42.39	<0.0001*
C	2.500	2.500	6.35	0.0304*
A^2	9.551	9.551	24.26	0.0006*
B^2	1.114	1.114	2.83	0.1235
C^2	3.636	3.636	0.92	0.3591
AB	0.000	0.000	0.000	1.0000
AC	2.000	2.000	5.08	0.0478*
BC	8.000	8.000	20.32	0.0011*
Lack of Fit	2.436	4.873	1.62	0.3037
C.V	8.7			
R^2	0.925			
R^2 Adjust	0.858			
Adeq Precision	14.49			

4.2.4 Three dimensional graph showing combined effects on bulk density of instant porridge from rice-pigeon pea flour blend

The relationship between the bulk density as the response and the selected variables was expressed in figure 4.3. Thus, synergistic effects of two of the factors at fixed concentration of one in optimizing the response (bulk density) was shown in three dimensional graph. In case of interaction between feed blend composition and feed moisture content (Figure 4.3), increase in concentration of both factors resulted in optimum bulk density. Similarly, Optimum bulk density and combination of the selected variables were obtained by analysing the response surface plot and derivative of the regression equation model generated. Similarly, residual analysis was used to validate fitness of the developed model. The variation between the actual and predicted values is termed the residual. Fig 4.4 are the graphical presentation of the relationship between the actual and predicted values of the bulk density of the instant porridge developed from rice-pigeon pea flour blend. Furthermore, the linear pattern of the graph shows that the models provide an accurate fit to the actual values.

(a)



(b)

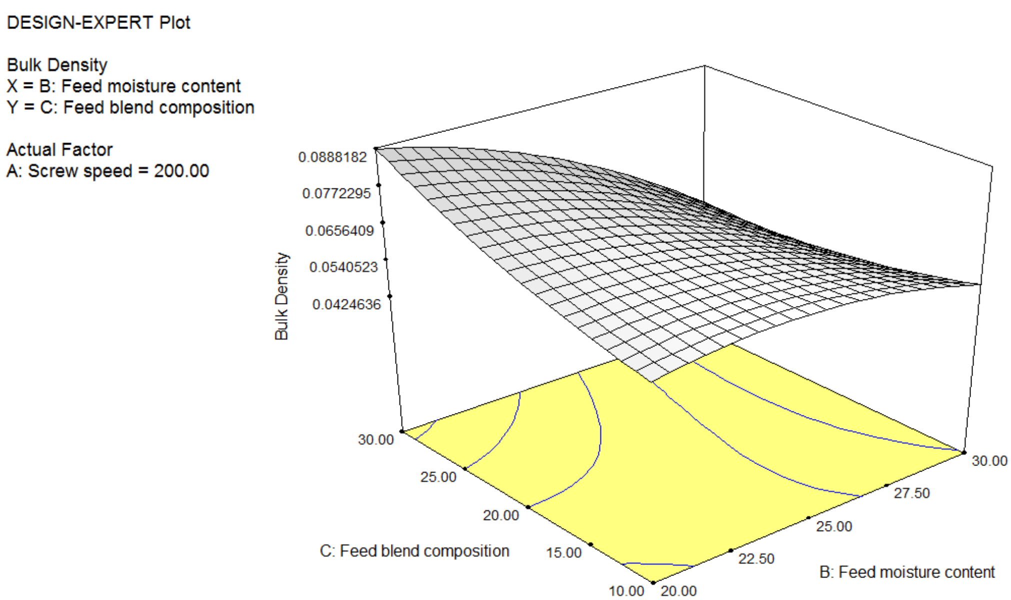


Figure 4.3: Three dimensional graph showing the combined effects of independent variables on bulk density of pigeon-pea blend.

(a) feed blend composition and screw speed (b) feed blend composition and feed moisture content (at fixed Screw Speed of 200rpm)

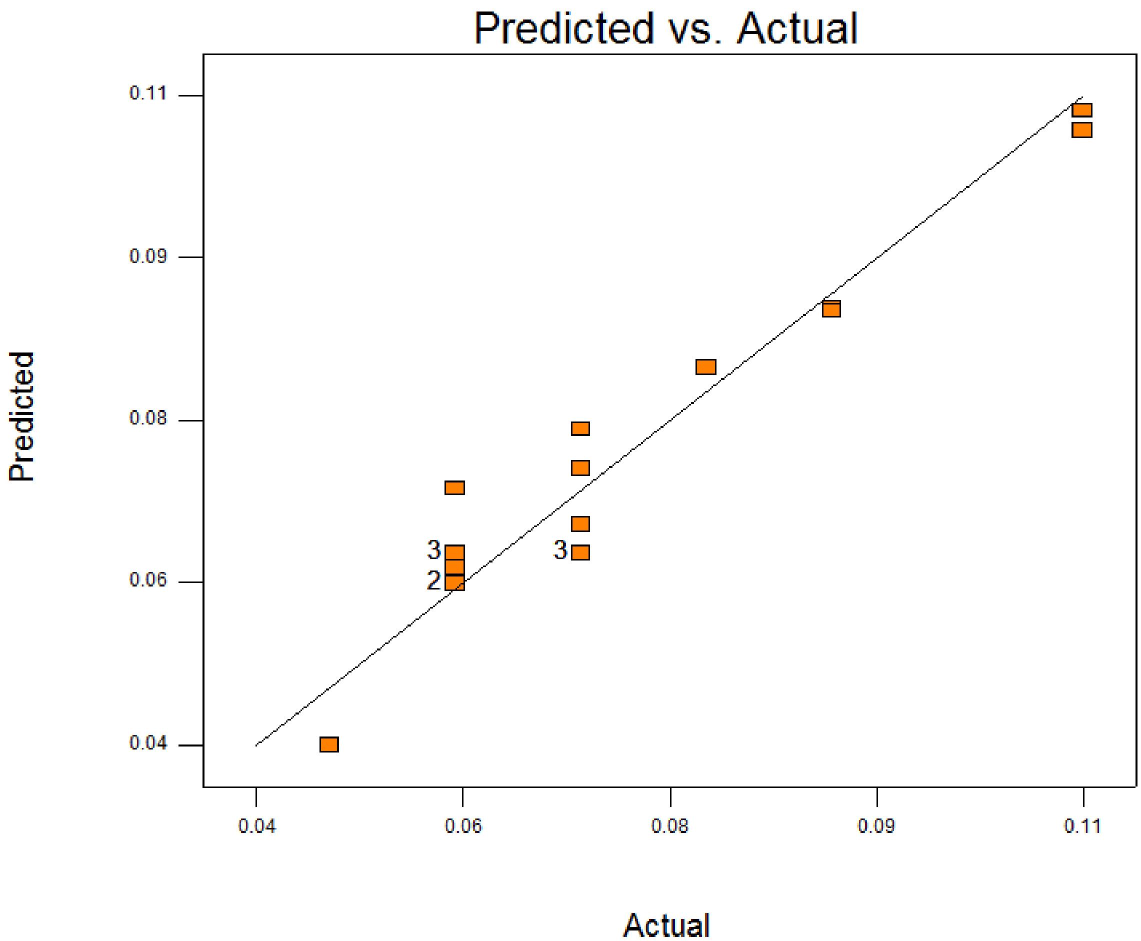


Fig 4.4: Residual graph for the actual versus predicted mean effects of processing variables on the bulk density of rice-pigeon pea flour blend.

4.2.5 Water absorption index

The developed quadratic model for water absorption index based on the three selected variables was expressed in equation 4.4:

Water Absorption Index = 5.09 - 0.17A + 0.30B - 0.48C + 0.15A^2 + 0.05B2 + 0.10C^2 - 0.12AB + 0.27AC + 0.53BC ………………………………………… (4.3)

Thus, the developed model was significant with a probability value of 0.0013 and a coefficient of variation of 5.72 which indicated an adequate precision of the experimental results (Table 4.4). Two each of linear and interaction terms were found to be significant at $p<0.05$ as indicated in Table 4.4. The fitness of the model was found to be 0.88 (R^2) suggesting that up to 88% of the variation in the rice-pigeon pea blend could be linked to the independent variables. Also, lack of fit value of 0.544 showed its level of in significance.; and the p-value obtained for the interaction of feed blend composition and feed moisture content was 0.0005; which suggested that the interaction was significant even at 99.99% confidence level (Table 4.4).

Table 4.4: Analysis of Variance of the Developed Quadratic Model for Water Absorption Capacity

Source	Sum of Squares	Mean Square	F-Value	P-Value
Model	6.79	0.75	8.42	0.0013*
A	0.28	0.28	3.15	0.1064
B	0.92	0.92	10.31	0.0093*
C	2.28	2.28	25.49	0.0005*
A^2	0.060	0.060	0.67	0.4323
B^2	6.264	6.264	0.070	0.7969
C^2	0.026	0.026	0.29	0.6002
AB	0.11	0.11	1.21	0.2979
AC	0.59	0.59	6.57	0.0283*
BC	2.28	2.28	25.42	0.0005*
Lack of Fit	0.74	0.15	4.83	0.544
C.V	5.72			
R^2	0.88			
R^2 Adjust	0.78			
Adeq Precision	12.12			

4.2.6 Three dimensional graph showing combined effects on water absorption index of instant porridge from rice-pigeon pea flour blend

The relationship between independent and response variables was shown in three dimensional graph. The effects of feed blend composition and screw speed on water absorption index when the feed moisture content was set at the middle level (25%) was shown in Figure 4.5a. The interaction was statistically significant ($p<0.05$) as indicated in Table 4.4. Similar pattern of 3D response was observed in Figure 4.5b; showing optimum water absorption index. In addition, residual analysis was used to validate fitness of the developed model. The variation between the actual and predicted values is termed the residual. Fig 4.6 are the graphical presentation of the relationship between the actual and predicted values of the water absorption index of the instant porridge developed from rice-pigeon pea flour blend. Furthermore, the linear pattern of the graph shows that the models provide an accurate fit to the actual values.

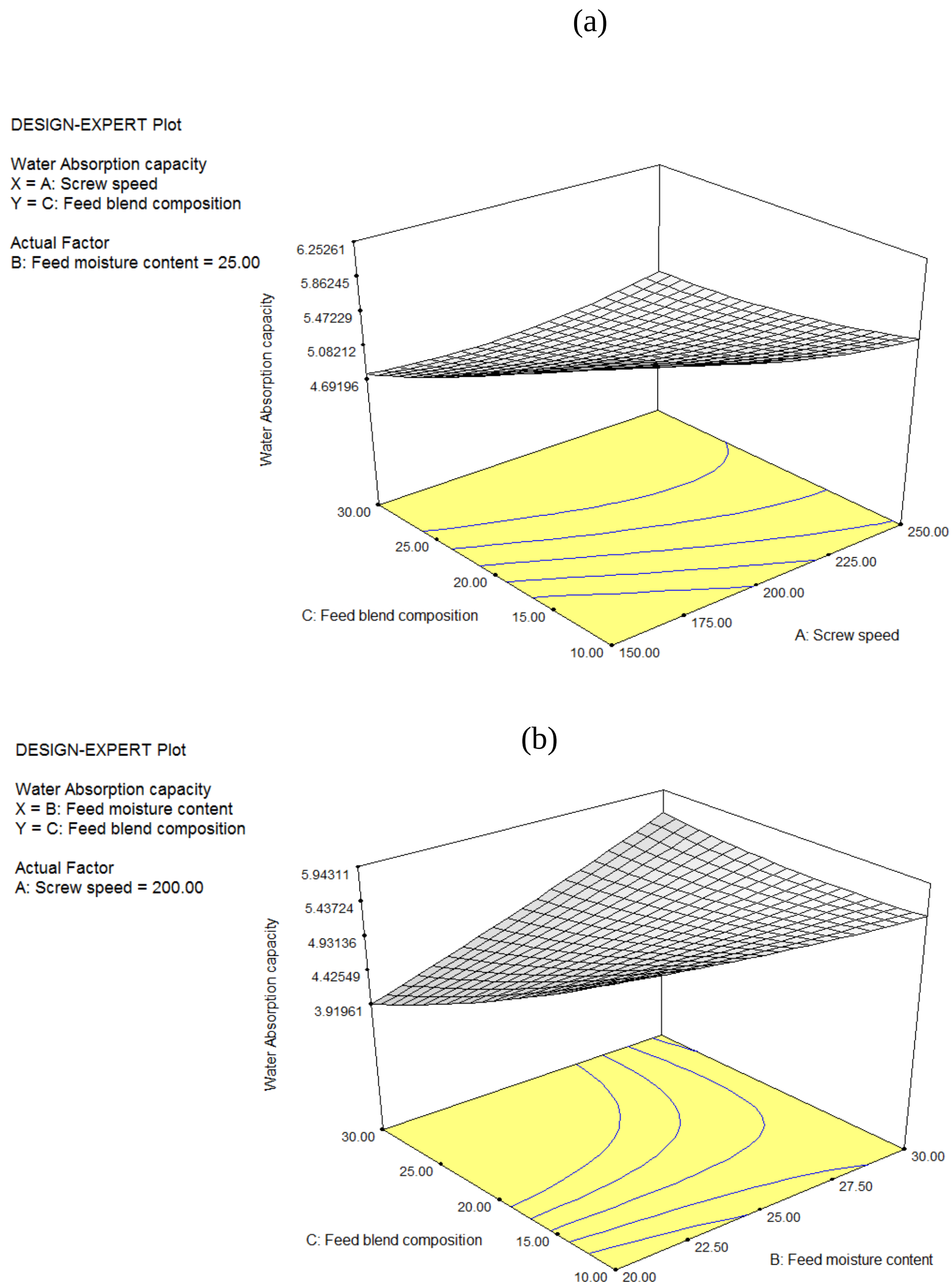


Figure 4.5: Three dimensional graph showing the combined effects of selected factors on water absorption index of rice- pigeon pea flour blend.

(a) feed blend composition and screw speed (b) feed blend composition and feed moisture content (at fixed Screw Speed of 200rpm)

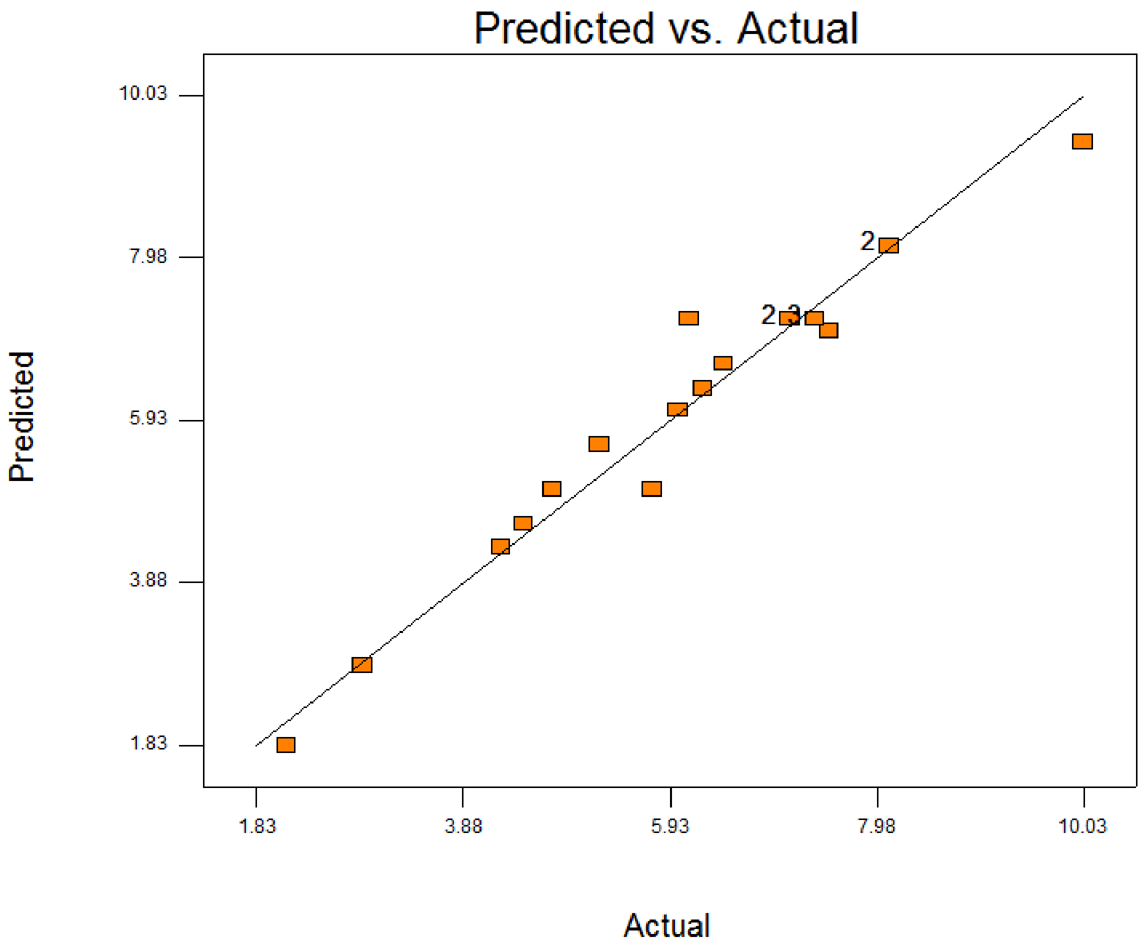


Fig 4.6: Residual graph for the actual versus predicted mean effects of processing variables on the water absorption index of rice-pigeon pea flour blend.

4.4: Optimization of Instant Porridge from Rice-Pigeon pea Flour Blend

The regression models showed the effects of independent variables on the functional properties of instant porridge from rice-pigeon pea flour blend based on experimental values (Table 4.1). The coefficient with one factor (A, B, C) followed by two or more factors (AB, AC, BC) and those with quadratic terms ($A^2{}_{1,}$ $B^2{}_{2,}$ $C^2{}_{3)}$ represent the three factors and quadratic effects respectively. The models indicated how the responses were affected by the input variables against the defined experimental region that will yield at optimum. By considering the optimization, it is expected that the porridge has to be based on the selection of the quality attributes of the functional properties in the optimization process. Similarly, the best optimum values for the production of instant porridges from rice-pigeon pea flour blend were located at 200 screw speed, 30% feed moisture content and 20% feed blend composition. At this combination, optimum expansion index of 9.56 ± 0.15, bulk density of 0.05 ± 0.01 g/ml and water absorption index of 5.55 ± 0.07 were obtained.

4.5 Validation of the Functional Properties of Rice-Pigeon Pea Blend Based on the Developed Quadratic Model

The models developed were observed to validate wheather the fitted values give an adequate approximation value to the real system. Danbaba *et al*. (2015) reported that until the models generated, indicated an adequate fit for optimization of the response model. The response model developed from this study has the highest value of R^2 which ranges from 95.9% (Expansion index), 92.5% (Bulk density) and 88.7% (Water absorption capacity) as indicated in Table 4.2 and 4.3, respectively. In addition, the adjusted R^2 for functional properties was also close to each response model showing satisfactory adjustment of the quadratic model to the experimental values.

Similarly, based on the results of the response values of CCD and the ANOVA Table; four sets of experiments were selected to serve as validation of the model as represented in Table 4.5. The four validated runs were termed as formulation 1, 2 3 and 4. Thus, formulation 3 resulted in maximum expansion index of 9.56 ± 0.15, bulk density of 0.05 ± 0.01 g/ml and water absorption index of 5.55 ± 0.07. Also, the formulations were further subjected to characterization involving proximate, mineral, amino acid compositions and sensory evaluation to be able to come up with the best formulation of rice-pigeon pea blend by extrusion cooking method that meet some nutritional specifications.

Table 4.5: Validation Experiments of the Developed Model for Rice-Pigeon Pea Blend

Experiment	Screw Speed (rpm)	Feed Moisture Content (%)	Feed Blend Composition (%)	Expansion Index	Bulk Density (g/ml)	Water absorption Index
Formulation 1	150	30	30	7.11 ± 0.47^{a}	0.06 ± 0.02^{a}	5.58 ± 0.18^{a}
Formulation 2	250	25	20	7.51 ± 0.15^{b}	0.09 ± 0.02^{a}	5.62 ± 0.14^{a}
Formulation 3	200	30	20	9.56 ± 0.27^{d}	0.05 ± 0.01^{a}	5.55 ± 0.07^{a}
Formulation 4	250	30	30	8.11 ± 0.15^{c}	0.06 ± 0.01^{a}	5.77 ± 0.16^{b}

Values are expressed as mean± Standard Deviation. Values with different superscripts on the same row are statistically different at $p<0.05$. Letter a, b, c, d represents superscripts with highest and lowest values.

4.6: Proximate Composition of Formulated Instant Porridge Produced from Rice-Pigeon Pea Blend using Extrusion Cooking Method

Proximate composition of the formulated rice-pigeon pea blend was shown in Table 4.6. The moisture content was found to be statistically different ($p<0.05$) among the 4 formulations as the concentration of pigeon pea increases. High moisture content of 7.08 ± 0.06 g/100g was obtained in Formulation 1 and the lowest value of 3.68 ± 0.10 g/100g was found in formulation 4. In case of protein content, formulation 3 (22.10 ± 0.01 g/100g) was statistically ($p<0.05$) higher than formulation 1 (17.49 ± 0.07 g/100g) as the pigeon pea composition increased. Similarly, the fat content was observed to be statistically ($p<0.05$) higher in formulation 2 with a value of (5.01 ± 0.02 g/100g) and lower in formulation 1 with a value of (2.50 ± 0.08 g/100g). The result of fibre content also indicated that formulation 4 (4.48 ± 0.02 g/100g) was found to be higher than formulation 2 (2.96 ± 0.07 g/100g) when screw speed was higher. Also, the ash content was observed to be statistically ($p<0.05$) higher in formulation 3 (1.47±0.02 g/100g); and the lower value was obtained in formulation 1 (1.07 ± 0.10 g/100g). The carbohydrate content obtained in this study was statistically ($p<0.05$) higher in formulation 1 (68.34 ± 0.01 g/100g) and the lowest value was obtained in formulation 2 (64.58 ± 0.03 g/100g). The calorific value (Kcal/100g) was found to be statistically ($p<0.05$) higher in formulation 2(386.57 ± 0.03 kcal/100g) than values observed in formulation 4(357.32 ± 0.06 kcal/100g).

Table 4.6: Proximate Composition (g/100g) of formulated Instant Porridge from Rice-Pigeon Pea Flour Blend

Parameters	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Moisture	7.08 ± 0.06^{d}	5.32 ± 0.08^{c}	4.15 ± 0.09^{b}	3.68 ± 0.10^{a}
Protein	17.49 ± 0.07^{a}	20.79 ± 0.04^{c}	22.10 ± 0.01^{d}	20.24 ± 0.05^{b}
Fat	2.50 ± 0.08^{a}	5.01 ± 0.02^{d}	3.28 ± 0.07^{b}	3.53 ± 0.04^{c}
Ash	1.07 ± 0.10^{a}	1.34 ± 0.04^{b}	1.47 ± 0.02^{c}	1.35 ± 0.03^{b}
Crude Fibre	3.52 ± 0.06^{b}	2.96 ± 0.07^{a}	4.05 ± 0.03^{c}	4.48 ± 0.02^{d}
Carbohydrate	68.34 ± 0.01^{d}	64.58 ± 0.03^{a}	65.24 ± 0.05^{b}	65.56 ± 0.04^{c}
Energy (Kcal)	365.82 ± 0.01^{c}	386.57 ± 0.03^{d}	378.88 ± 0.04^{b}	357.32 ± 0.06^{a}

Values are expressed as mean± Standard Deviation. Values with different superscripts on the same row are statistically different at $p<0.05$. Letter a, b, c, d represents superscripts with highest and lowest values.

Formulation 1 (150 screw speed, 30 feed moisture content and 30 feed blend composition)

Formulation 2 (250 screw speed, 25 feed moisture content and 20 feed blend composition)

Formulation 3 (200 screw speed, 30 feed moisture content and 20 feed blend composition)

Formulation 4 (250 screw speed, 30 feed moisture content and 30 feed blend composition)

4.7: Mineral Compositions of Formulated Instant Porridge Produced from Rice-Pigeon Pea Flour Blend

Table 4.7 revealed the mineral composition of formulated instant porridge, the sodium content was found to be statistically ($p<0.05$) higher in formulation 3 (2.86 ± 0.05 mg/100g) and the lowest value was found in formulation 1 (1.92 ± 0.08 mg/100g). Also, potassium content was found to be statistically ($p<0.05$) higher in formulation 3 (5.01 ± 0.01 mg/100) than values obtained in formulation 1 (4.59 ± 0.03 mg/100g) as the pigeon pea composition increased. Similarly, Calcium content was highest in formulation 3 (3.41 ± 0.07mg/100g) and lowest in formulation 1 (2.46 ± 0.02 mg/100g). Phosphorus content was found to be statistically ($p<0.05$) higher in formulation 1 (1.52±0.10 mg/100g); and lowest values was observed in formulation 2 (1.00 ± 0.15 mg/100g). Magnesium content was statistically ($p<0.05$) higher in formulation 1 (2.99 ± 0.05 mg/100g) than values obtained in formulation 3 (1.59 ± 0.10 mg/100g). Similarly, formulation 3 showed the highest iron content of (12.64 ± 0.03 mg/100g) and zinc content of (9.33 ± 0.02 mg/100g) and the lowest values (for iron and zinc) were observed in formulation 2 (11.24 ± 0.02 mg/100g) and formulation 1 (5.96 ± 0.06 mg/100g) respectively.

Table 4.7: Mineral Composition (mg/100g) of formulated Instant Porridge from Rice-Pigeon Pea Flour Blend

Parameters	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Na	1.92±0.08[a]	2.65±0.06[b]	2.86±0.05[b]	2.77±0.04[b]
K	4.59±0.03[a]	4.65±0.04[a]	5.01±0.01[b]	4.63±0.02[a]
Ca	2.46±0.02 [a]	2.55±0.05[b]	3.41±0.07[d]	2.86±0.03[c]
P	1.52±0.10[c]	1.00±0.15 [a]	1.34±0.12[b]	1.23±0.11[b]
Mg	2.99±0.05[c]	1.93±0.03[b]	1.59±0.10 [a]	1.61±0.09 [a]
Fe	11.89±0.04[b]	11.24±0.02 [a]	12.64±0.03[d]	12.10±0.06[c]
Zn	5.96±0.06 [a]	8.62±0.08[c]	9.33±0.02[d]	6.74±0.03[b]

Values are expressed as mean± Standard Deviation. Values with different superscripts on the same row are statistically different at $p<0.05$. Letter a, b, c, d represents superscripts with highest and lowest values.

Formulation 1 (150 screw speed, 30 feed moisture content and 30 feed blend composition)

Formulation 2 (250 screw speed, 25 feed moisture content and 20 feed blend composition)

Formulation 3 (200 screw speed, 30 feed moisture content and 20 feed blend composition)

Formulation 4 (250 screw speed, 30 feed moisture content and 30 feed blend composition)

4.8: Essential Amino Acid Composition of Formulated Instant Porridge Produced from Rice-Pigeon Pea Flour Blend

The results of essential amino acids composition of formulated instant porridge produced from rice-pigeon pea blend are presented in Table 4.8.

The leucine content was found to be statistically higher in formulation 4 (5.60 ± 0.07 g/100g protein); than formulation 1 (4.17 ± 0.03 g/100g protein). For isoleucine, formulation 3 (3.30 ± 0.09 g/100g protein) was statistically ($p<0.05$) higher than value obtained in formulation 2 (2.94 ± 0.08 g/100g protein). The lysine content of the rice-pigeon pea based porridge was observed to be statistically ($p<0.05$) higher in formulation 3 (3.44 ± 0.03 g/100g protein) and lower in formulation 4 (3.16 ± 0.05 g/100g protein) as the concentration of pigeon pea increases. Similarly, phenylalanine was observed to be statistically ($p<0.05$) higher in formulation 3 (4.34 ± 0.08 g/100g protein); and statistically ($p<0.05$) lower in formulation 1 (3.01 ± 0.04 g/100g protein). In case of valine content, it was observed that higher value was obtained in formulation 3 (3.84 ± 0.06 g/100g protein) than formulation 1 (3.14 ± 0.07 g/100g protein).

Similarly, the result of methionine content of rice-pigeon pea porridge was found to be statistically ($p<0.05$) higher in formulation 3 (1.44 ± 0.02 g/100g protein) and lower in formulation 1 (1.15 ± 0.09 g/100g protein). The Arginine content of the formulated instant porridge was statistically ($p<0.05$) higher in formulation 3 (4.30 ± 0.07 g/100g protein) and the lowest value was observed in formulation 2 (3.44 ± 0.04 g/100g protein). The result of Histidine content showed that formulation 3 (2.27 ± 0.05 g/100g protein) was statistically ($p<0.05$) higher and lower in formulation 2 (1.85 ± 0.07 g/100g protein). Furthermore, threonine was observed to be statistically ($p<0.05$) higher in formulation 3 (3.49 ± 0.03 g/100g protein); than in formulation 2 (2.99 ± 0.06 g/100g protein). The tryptophan content was statistically ($p<0.05$) higher in formulation 1 (1.20±0.09 g/100g protein) and 3 (1.20 ± 0.08 g/100g protein) and lower in formulation 2 (0.97 ± 0.14 g/100g protein).

Table 4.8: Essential Amino Acid Compositions (g/100g) of Instant Porridge from rice-pigeon pea blend formulations

Parameters	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Leucine	4.17±0.03 ^{a}	5.19±0.02^{b}	5.53±0.10^{c}	5.60±0.07^{c}
Isoleucine	3.27±0.01^{c}	2.94±0.08 ^{a}	3.30±0.09^{c}	3.14±0.02^{b}
Lysine	3.16±0.05^{b}	3.34±0.03^{c}	3.44±0.04^{d}	3.10±0.01 ^{a}
Phenylalanine	3.01±0.04 ^{a}	3.54±0.05^{b}	4.34±0.08^{d}	3.63±0.03^{c}
Valine	3.14±0.07 ^{a}	3.24±0.02^{b}	3.84±0.06^{d}	3.72±0.04^{c}
Methionine	1.15±0.09^{a}	1.28±0.01 ^{b}	1.44±0.02^{c}	1.39±0.10^{c}
Arginine	4.03±0.03^{b}	3.44±0.04 ^{a}	4.30±0.07^{d}	4.13±0.06^{c}
Histidine	2.20±0.02^{c}	1.85±0.07 ^{a}	2.27±0.05^{c}	2.04±0.08^{b}
Threonine	3.38±0.07 ^{c}	2.99±0.06 ^{a}	3.49±0.03^{d}	3.27±0.09^{b}
Tryptophan	1.20±0.09^{c}	0.97±0.14 ^{a}	1.20±0.10^{c}	1.10±0.11^{b}

Values are expressed as mean± Standard Deviation. Values with different superscripts on the same row are statistically different at $p<0.05$. Letter a, b, c, d represents superscripts with highest and lowest values.

Formulation 1 (150 screw speed, 30 feed moisture content and 30 feed blend composition)

Formulation 2 (250 screw speed, 25 feed moisture content and 20 feed blend composition)

Formulation 3 (200 screw speed, 30 feed moisture content and 20 feed blend composition)

Formulation 4 (250 screw speed, 30 feed moisture content and 30 feed blend composition)

4.9: Sensory Attributes of Formulated Instant Porridge Produced from Rice-Pigeon Pea Blend

Table 4.9 showed the sensory properties of the developed instant porridge, the result of taste was observed to be statistically ($p<0.05$) higher in formulation 3 (7.34 ± 0.09) than formulation 1 (7.09 ± 0.06). Similarly, texture was observed to be statistically ($p<0.05$) higher in formulation 3 (6.09 ± 0.01) and lower in formulation 1 (5.89 ± 0.04). Also, formulation 3 (4.98 ± 0.01); was observed to be statistically ($p<0.05$) higher in flavour, colour (6.55 ± 0.01) and lower value were obtained in formulation 1 (6.12 ± 0.07). While, the General acceptability was found to be statistically ($p<0.05$) higher in formulation 3 (6.68 ± 0.06); than what was obtained in formulation 1 (6.38 ± 0.05).

Table 4.9: Sensory attributes of Instant Porridge formulation from Rice-Pigeon Pea Blend

Parameters	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Taste	7.09 ± 0.06^{a}	7.10 ± 0.07^{a}	7.34 ± 0.09^{b}	7.21 ± 0.05^{b}
Texture	5.89 ± 0.04^{a}	5.92 ± 0.03^{a}	6.09 ± 0.01^{c}	6.00 ± 0.02^{b}
Flavor	4.53 ± 0.03^{a}	4.91 ± 0.02^{c}	4.98 ± 0.01^{c}	4.65 ± 0.04^{b}
Color	6.12 ± 0.07^{a}	6.22 ± 0.05^{b}	6.55 ± 0.01^{c}	6.51 ± 0.03^{c}
Acceptability	6.38 ± 0.05^{a}	6.63 ± 0.04^{b}	6.68 ± 0.06^{b}	6.66 ± 0.02^{b}

Values are expressed as mean± Standard Deviation. Values with different superscripts on the same row are statistically different at $p<0.05$. Letter a, b, c, d represents superscripts with highest and lowest values.

Formulation 1 (150 screw speed, 30 feed moisture content and 30 feed blend composition)

Formulation 2 (250 screw speed, 25 feed moisture content and 20 feed blend composition)

Formulation 3 (200 screw speed, 30 feed moisture content and 20 feed blend composition)

Formulation 4 (250 screw speed, 30 feed moisture content and 30 feed blend composition)

CHAPTER FIVE

5.0 DISCUSSION

Functional properties are among the important attributes that describe the product quality in food formulation (Filli *et al*., 2013). Thus, extrusion process is generally dependent on some important properties including moisture, feed content, particle size, temperature, screw speed, screw configuration and die plate (Meng *et al.*, 2010). The combined effect of these properties and the nutrient composition of the extrudates determine the quality of the final product. Among the selected functional properties, expansion index of the extrudates was reported to be dependent on feed moisture content (Ding *et al.*, 2005). Similarly, the higher value of expansion index observed in run 12 could be as a result of increase in feed moisture content and screw speed at decreased feed composition. Seker (2005) reported that increasing screw speed with decrease in feed composition improved the expansion index during extrusion of soybean-corn flour. High starch content may lead to high expansion index especially where significant gelatinization occurs due to dough viscosity (Seker, 2005). Low screw speed with increased feed composition requires high shear force for better dough development (Filli *et al*., 2013). In case of extrudates obtained from rice-based expanded snack, expansion index was found to be significantly influenced by moisture content and barrel temperature (Ding *et al.*, 2005). Also, increase in protein content (based on feed blend composition) could cause swelling which collapses because of its visco-elastic property (swelling of the extrudates from the die). Iwe and Ngoddy (1998) obtained similar findings for low expansion index of extruded soybean and sweet potato blend.

Bulk density serves as an important functional property for extruded products which aids in assessing the level of expansion associated with extrusion cooking process (Filli *et al*., 2013).

The feed moisture content strongly influenced the bulk density values as observed in this study, suggesting an optimum relationship since the lowest value of bulk density in run 12 (0.05 g/ml) was observed when the moisture content was at its high level (30 %); (Table 4.1). Similarly, high temperature and high screw speed have been linked to low bulk density which could be due to starch gelatinization under such conditions (Hagenimana *et al.,* 2006). Also, Ding *et al.* (2006) reported that increase in screw speed tend to decrease the bulk density. The high dependence of bulk density and expansion index on feed moisture content would reflect its influence on elasticity characteristics of the starch-based material. Increased feed moisture content during extrusion may affect the elasticity of the material through plasticization of the melt developed during extrusion and this could result in an expanded structure with low density (Suresh *et al.,* 2013).

Water absorption index is a measure of starch digestibility and is dependent on the degree of gelatinization and dextrinization (Pardhi *et al.,* 2017). The results of instant porridge developed from rice-pigeon pea indicated that screw speed influenced water absorption index (3.96-6.26) as obtained in Table 4.1. Thus, presence of polar head groups in the developed blend determines its interaction with water molecules. Feed moisture content acts as plasticizer during extrusion cooking by reducing the degradation of granules and increasing the water absorption index (Hagenimana *et al.,* 2006). Similarly, high screw speed was reported to support low water absorption during extrusion cooking of starch based binders (Pan *et al.,* 1998). The amount of water associated to proteins is closely related with its amino acids and increases with the number of charged residues, conformation, hydrophobicity, pH, temperature, ionic strength and protein concentration (Suresh *et al.,* 2013).

The relationship between independent variables and responses as well as residual graph were indicated in figure 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6. The three dimensional response surface plots were based on the coefficient presented in table 4.2, 4.3 and 4.4, respectively. Residual analysis was used to validate fitness of the developed model. The variation between the actual and predicted values is termed the residual. Furthermore, the linear pattern of the graphs showed that the models were close to each other which provide an accurate fit to the actual values (Danbaba *et al.*, 2015). Optimum levels of the response variable and the combination of input variables were obtained by analyzing the response surface plots, residual graph and the model equation generated. Similarly, the best optimum levels for independent variables for the production of instant porridge developed from rice-pigeon pea flour blend were set at 200 screw speed, 30% feed moisture content and 20% feed blend composition.

Proximate composition of the formulated rice-pigeon pea blend was shown in Table 4.6 The moisture content was found to be statistically ($p<0.05$) lower among the 4 formulations as the concentration of pigeon pea decreases. The results suggested that variation in moisture content was associated with the higher screw speed. Similarly, higher screw speed lead to low quantity of water absorbed by the extrudates (Harper and Jansen, 1985). The findings of this study indicated that the extruded products had low moisture content that could extend its shelf life. Harper and Jansen (1985) reported that moisture content between 6% and 10% aids in prolonging the shelf life of dry food products; and above this range, the shelf life stability of the products could be hindered by both chemical and microbiological agents.

In case of protein content, formulation 3 was observed to be statistically ($p<0.05$) higher among the formulations (Table 4.6). This increase could be attributed to addition of pigeon pea composition. Filli *et al.* (2011) showed that fortification of millet with cowpea for development of fura extrudates resulted in increment of protein content from 11.23% to 16.23 % due to concentration of cow pea. Similarly, the fat content was observed to be statistically ($p<0.05$) higher in formulation 2 (5.01 ± 0.02 g/100g) and lower in formulation 1 (2.50 ± 0.08 g/100g). Low fat content observed in formulation 2 could be linked to high screw speed and low feed blend composition (Table 4.6) since most legumes such as pigeon pea contain less than of fat. The reduction of fat content observed in this study was in agreement with the findings of Anuonye *et al.* (2012) where significant reduction in fat content was reported when soybean was blended with acha. High screw speed was also linked to lower fat content as reported by Filli *et al.* (2013). Dietary fats are beneficial in the body because of their function as carriers of fat soluble vitamins in the diet and as mediators of some physiological processes associated with growth and development, inflammation and brain function (Gbenyi *et al*., 2016). Fibre is very important in maintaining good health as increased risk of coronary heart disease could occur to individuals who consume low levels of fibre over time (Singh *et al.*, 2007). It promotes beneficial effects associated with lowering of cholesterol (Singh *et al.*, 2007). The crude fiber content was found to be statistically ($p<0.05$) higher in formulation 4 (4.48 ± 0.02 g /100g) than formulation 2 (2.96 ± 0.07 g /100g). The significant ($p<0.05$) increase observed in formulation 4 could be due to the increase in the concentration of pigeon pea composition. The result of ash content observed that formulation 3 (1.47 ± 0.02 g /100g) was statistically ($p<0.05$) higher than formulation 1 (1.07 ± 0.10 g /100g). In this study, the significant ($p<0.05$) differences in ash content is associated with higher screw speed and feed moisture content in the formulations. El-Samahy *et al.* (2007) showed that blending of rice with cactus pear resulted in significant ($p<0.05$) differences in ash content.

The carbohydrate content showed that formulation 1 (68.34 ± 0.01 g /100g) was statistically ($p<0.05$) higher and lower in formulation 2 (64.58 ± 0.02 g /100g). This increase in formulation 1 could be attributed to low screw speed and high feed blend composition. Higher value observed in carbohydrates could be linked to the raw material that were not affected by processing. Energy store of food products is generally indicated by its carbohydrate content. Similarly, variation in pigeon pea composition affected the overall carbohydrate content of the blend as observed by Filli *et al.* (2011). Similarly, the differences in calorific values of the developed rice-pigeon pea blend would promote its wider application and utilization in food industry; especially in formulation of ready- to-eat foods (Jisha *et al.,* 2010).

Minerals in foods are chemical components that cannot be ordinarily synthesized and are required for normal metabolic activities of the body (Kadan *et al.,* 2003). However, sodium is one of the minerals whose high intake is considered as a factor in the etiology of hypertension; hence its low intake is encouraged (Kadan *et al*., 2003). The results of sodium content showed that formulation 3 (2.86 ± 0.05 mg /100g) was statistically ($p<0.05$) higher than formulation 1 (1.92 ± 0.08 mg /100g). This increase could be as a result of the increase in screw speed when significant gelatinization occurs during extrusion of the extrudates (Kanu *et al.,* 2009). Also, Higher screw speed favored sodium content due to elimination of phytic acid (Kanu *et al.,* 2009). Potassium is primarily an intracellular cation, which is bound to protein and functions together with sodium in maintaining the normal pH (Adeyeye and Agesin, 2007). The results of potassium content indicated that formulation 3 (5.01±0.01 mg/100g) was statistically higher and lower in formulation 1 (4.59 ± 0.03 mg /100g). This could be due to activities of protease during extrusion which could serve as an added advantage for product development, especially complementary food where potassium is an important macro nutrient among other minerals.

The results of calcium content indicated that formulation 3 (3.41 ± 0.07 mg /100g) was statistically ($p<0.05$) higher and lower in formulation 1 (2.46 ± 0.02 mg /100g). Higher calcium content has been attributed to rice and pigeon pea as a good dietary sources of minerals. Calcium is the most important mineral that is needed by the body and its deficiency is more prevalent than any other minerals (Kanu *et al.*, 2009). Also, Singh *et al*. (2000) reported the increase in calcium, phosphorus and iron content during production of cereal based extrudates which was attributed to feed composition and water content. Calcium, phosphorus and vitamin D combined together to prevent rickets in children and Osteomalacia (the adult rickets) as well as osteoporosis (bone thinning) among older people (Adeyeye and Agesin, 2007). The findings in this work indicated higher magnesium and phosphorus contents in formulation 1 than formulation 3 (Table 4.7). This could be due to activities of protease, lipase and amylase during gelatinization of the extrudates which could serve as an added advantage for product quality. Similarly, Magnesium as an activator of many enzyme systems aids in maintaining the electrical potential of the nerve cells (Adeyeye and Agesin, 2007). It assists in muscle contraction, blood clotting, and the regulation of blood pressure and lung functions (Swaminathan, 2003). Minerals like iron, calcium and zinc are often added to food for the improvement of nutritional composition (Camire *et al.*, 1990). In this study, the result of both iron and zinc contents were observed to be statistically higher in formulation 3. This increase could be attributed to destruction of antinutrients (phytic acid) during extrusion of the extrudates. Similarly, iron and zinc act as cofactors for enzymes during normal metabolic processes (Agunbiade and Ojezele, 2010). In addition, iron is needed for the prevention of anaemia; while zinc is a component of living cells and essential for assisting enzyme reaction and wound healing (Agunbiade and Ojezele, 2010).

Essential amino acids are needed to be supplied in the diet for growth and development. Table 4.8 showed the essential amino acids composition of instant porridge from rice-pigeon pea blend formulation; where formulation 3 were statistically ($p<0.05$) higher in limiting amino acids (lysine and methionine) and all other essential amino acids due to feed blend composition (pigeon pea). Filli *et al.* (2011) reported similar findings when extruded fura was produced from millet-cowpea flour composites. Lysine and methionine are the limiting essential amino acid in rice and pigeon pea, respectively. Lysine is however heat labile and thus; focusing on lysine retention during the extrusion process is of particular importance. Paes and Maga (2004); Anounye *et al*. (2010) had reported depletion of some amino acids as a result of extrusion cooking. Singh *et al*. (2007) also showed that mild extrusion conditions improve the nutritional quality including the amino acid contents; while high extrusion conditions associated with high screw speed (>250 rpm), low moisture (<20%) and/or improper formulation (e.g. presence of high-reactive sugars) affect the nutritional quality of extrudates. Thus, all the essential amino acids of the extrudates observed in this work were in sufficient quantities to meet the requirements of both children and adult nutrition.

The results of sensory properties of instant porridge produced from rice-pigeon pea flour blend indicated that formulation 3 were statistically ($p<0.05$) higher in taste (7.34 ± 0.09), texture (6.09 ± 0.01) and flavour (4.98 ± 0.02) which could be attributed to higher screw speed and feed moisture content (Table 4.9). This result is in agreement with report of Iwe (2001) who observed the increase in texture when cereal was blended with legumes. He also suggested that taste and flavor are physiologically and physically connected with one another depending on the respondents. Similarly, results from this work indicated that taste and flavor of the extrudates were enhanced during extrusion. Furthermore, Iwe (2001) explained that slight variation of values observed in taste and flavor could be due to higher screw speed and feed moisture content. In addition to color rating (6.55 ± 0.01) and general acceptability (6.68 ± 0.06) of extrudates, formulation 3 were statistically ($p<0.05$) higher when the feed moisture content increases. These results were in agreement with Rampersad *et al.* (2003) who reported the degree of likeness in all the sensory attributes.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In this work, different formulated rice-pigeon pea flour blends were produced using extrusion cooking method by Central composite design. The optimum independent variables were established at 200 screw speed (rpm), 30% feed moisture content and 20% feed blend composition with optimum expansion index of 9.56 ± 0.15, bulk density of 0.05 ± 0.01 g /ml and water absorption index of 5.55 ± 0.07. Out of the four formulations prepared for validation, formulation 3 was enhanced in terms of functional properties, nutritional value and sensory attributes. In conclusion therefore, convenient complementary foods can be produced from rice-pigeon pea blend using extrusion cooking method which improved the nutritional and sensory properties of the products.

6.2 Recommendation

It is recommended that instant porridge produced from rice-pigeon pea blend should be scaled up for local and commercial purposes to enable the utilization of the products by children as ready-to-use therapeutic diet. Further studies should be conducted on the vitamin content and nutrient digestibility of the products. Also, nutrition education and encouragement by the policy makers to adopt this and many other blends using locally available raw materials could help in management of malnutrition related cases in Nigeria.

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APPENDIX I

Sensory evaluation form

Name…………………………………………….

Date……………………………………………….

The scale below was used to express people‘s attitude towards the products taste, color, flavor, texture and general acceptability.

Description Score

Like extremely...……………………………………………..………9

Like very much…………………………………………………….…8

Like moderately ……………………………………….…..………7

Like slightly ……………………………………………….…..............6

Neither like nor dislike..…………………………………....…….…5

Dislike slightly……………………………………………………..…..4

Dislike moderately ……………………………………………...........3

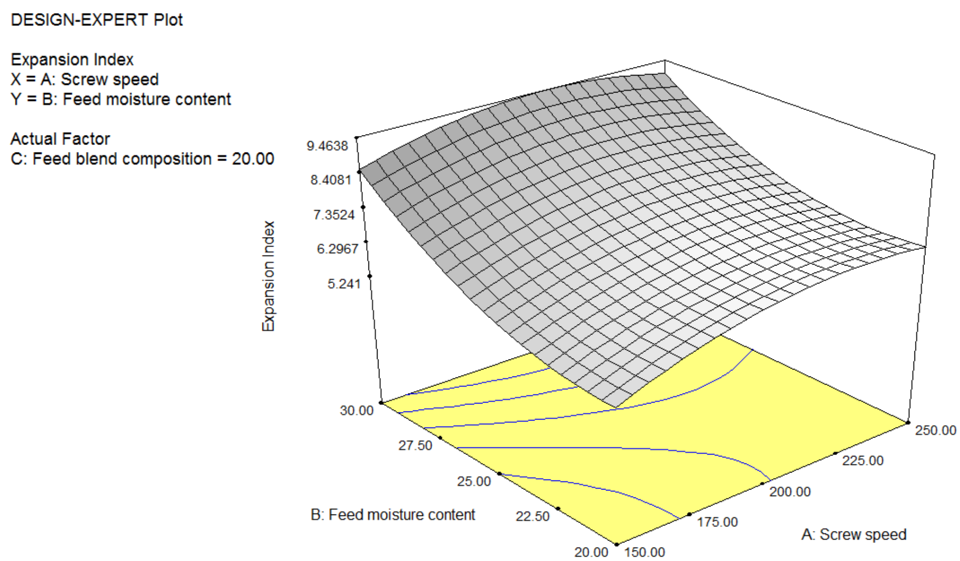
Dislike very much ………………………………………………….……2

Dislike extremely ………………………………………………………..1

Samples	Taste	Colour	Flavour	Texture	General Acceptability
Formulation 1					
Formulation 2					
Formulation 3					
Formulation 4					

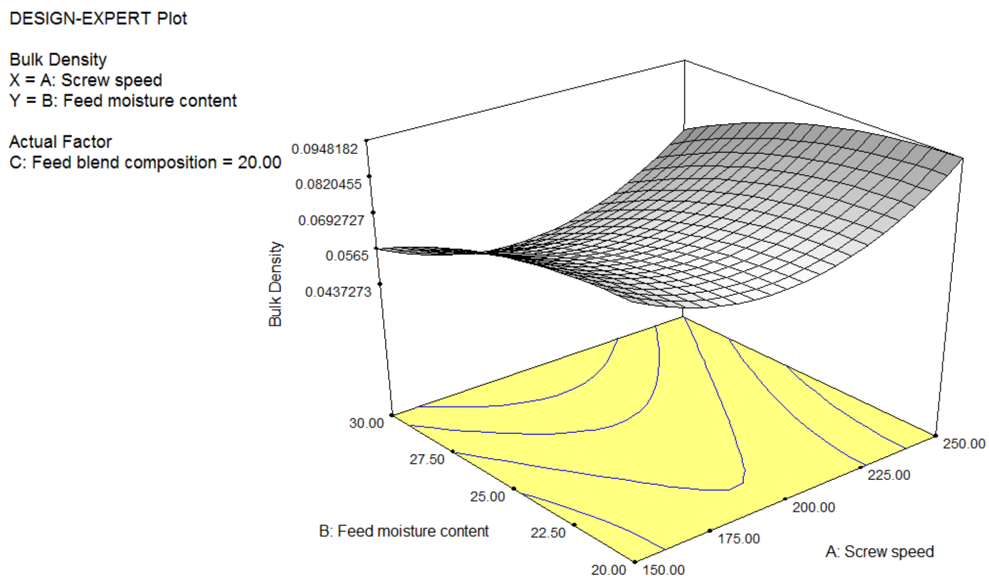
APPENDIX II

Three Dimensional Graph of expansion index showing relationship between independent variables (screw speed, feed moisture and feed blend composition)



APPENDIX III

Three Dimensional Graph of bulk density showing relationship between independent variables (screw speed, feed moisture and feed blend composition)



APPENDIX IV

Three Dimensional Graph of water absorption index showing relationship between independent variables (screw speed, feed moisture and feed blend composition)