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DEVELOPMENT OF COMPLEMENTARY FOOD FROM SORGHUM BLENDED WITH PEANUT

Mahamed Dol, MSc

Principal Investigator

Ass.Prof. Abdulkarim Mohamed, MSc

Hodo Mohamed, BSc

Co-Investigators

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1. INTRODUCTION

1.1. Background

Food crops have continued to be an important source of human nutrition as they are the major sources of nutrients, proteins, and calories for populations, especially in developing nations. Sorghum (Sorghum bicolor) is one of the oldest known cereal grains and ranked fifth in the world after wheat, rice, maize, and barley in terms of production ADDIN EN. Sorghum (Sorghum bicolor L.) as a potential source of bioactive substances and their biological Critical Reviews in Food Science and Nutrition . It constitutes the main food grain for over 750 million people who live in the semi-arid tropics of Africa, Asia, and Latin America. The largest group of producers is small-scale subsistence farmers with minimal access to production inputs such as fertilizers, pesticides, improved seeds (hybrids or varieties), good soil and water, and improved credit facilities for their production (Jiru & Usmane, 2021). The most important producers are the United States, Nigeria, Sudan, Mexico, China, India, Ethiopia, Argentina, Burkina Faso, Brazil, and Australia. Burkina Faso is the world leader in sorghum production and consumption per inhabitant (Dicko, Gruppen, Traoré, Voragen, & Van Berkel, 2006).

More than 35% of sorghum is grown directly for human consumption. The rest is used primarily for animal feed, alcohol production, and industrial products (Pontieri et al., 2012). This crop sustains the lives of the poorest, rural people. Availability, storage, utilization, and consumption of their food crop will significantly contribute to household food security and nutrition of the inhabitants of this area. Sorghum while playing a crucial role in food security in Africa, its also a source of income for households (Tadele, 2019). Although sorghum is grown mainly for the energy stored in its starch, the protein quality is critically important in developing countries where the human diet consists mainly of cereal (Lorenzo et al., 2017).

Sorghum protein is higher than that of rice, equal to or higher than that of maize, and roughly equivalent to that of wheat (Rooney & Serna-Saldivar, 2000). Protein content and composition varies due to genotype, water availability, soil fertility, temperature, and environmental condition during grain development (Mofokeng, Shimelis, & Laing, 2017). Sorghums are rich sources of micronutrients (minerals and vitamins) and macronutrients (carbohydrates, proteins, and fat). Sorghum-based foods have continued to be nutritionally deficient and organoleptically inferior. This is largely due to the presence of anti-nutritional factors (ANF) such as tannin and phytic acid

inhibitors which bind these food ingredients into complexes making them unavailable for human nutrition (Ogbonna, Abuajah, Ide, & Udofia, 2012).

Sorghum may be an alternative food for people who are allergic to gluten. Also, Sorghum has health benefits such as inhibiting cancer tumor growth, protecting against diabetes and insulin resistance, being safe for people with celiac disease, helping manage cholesterol, antioxidants in sorghum high relative to other grains, and fruits, and also sorghum may help treat human melanoma.

Peanut (Arachis hypogeae L), is an important energy-dense source of plant protein usually consumed after roasting and typically processed into different forms such as peanut butter, sweets, chocolate, cakes, and other peanut butter and jam sandwiches are very popular with raw roasted, shelled or unshelled corms of peanut being available throughout the year (Singh et al., 2021). Peanut (Khalid et al., 2022), also known as groundnut, is one of the most important sources of vegetable oil and protein. Peanuts are believed to have originated in the Central American region where they spread to other parts of the world. Peanuts are often enriched with health-benefiting nutrients that are essential to human health. They are actually legumes but are the most frequently eaten nut and more than 300 different varieties of peanut are grown worldwide (Sobowale, Adebo, & Mulaba-Bafubiandi, 2019). In recent years, different approaches and consequent legume-based food industries have been using peanuts as alternative protein supplements to address protein deficiency in meals. This protein deficiency is still prevalent, particularly in developing countries, thus necessitating the development of dietary balanced foods to address this challenge (Meena, Das, Yadav, & Lal, 2018).

In Ethiopia, the economy is predominantly agrarian, where 95% of the farmland was cultivated by smallholder farmers and 90% of the total agricultural output comes out of them (Gebre, Workiye, & Haile, 2021). Agricultural commercialization brings about sustainable food security, and welfare and enhances vertical and horizontal market linkages (Tirkaso, 2013). In Ethiopia, cereals are the major food crops both in terms of the area they are planted and the volume of production obtained. Out of the total grain crop area, 79.83% (11,610,331 ha) was under cereals and it contributed 87.08% (about 283,922,484 quintals) of the grain production central statistical agency (Haile, Gebre, & Workye, 2022).

In Ethiopia Sorghum is processed at a household level using traditional means, such as small grain mills. The grain is consumed in various forms, including Injera (Kimis,Loxoox), Soor(Shuuro),

porridge, nefro, and local drinks. So, to improve the nutritional quality of cereal-based traditional diets in Ethiopia, the use of peanut flour as a protein supplement has often been suggestible. So, sorghum, and peanut could be exploited since they are easy to access in the region. The product could be prepared at home and it will substitutable with CSB+, especially during food pipeline breakdown to avoid relapses. Therefore, the aim of this study were the influence of different composites of sorghum and peanut flour on proximate composition and functional characteristics, after which the composites were developed into SBP flour and their sensory characteristics were evaluated.

1.2. Statement of the problem

Malnutrition is the most common pathological condition of deficiency/excess of necessary nutrients. It is a significant cause of morbidity and mortality in children worldwide. It causes 60% of deaths of children in developing countries. Protein-energy malnutrition (PEM) it's a wide spectrum of malnutrition primarily affecting children from developing countries (infants, pre-school) and its severe clinical forms included Marasmus, Kwashiorkor, and a mixed feature called marasmus-kwashiorkor. The milder forms of PEM are stunting (chronic form) and wasting (acute)(Ahmed, Massaad, Abdalla, Omar, & Adam, 2019). Moderate acute malnutrition (MAM) is estimated to affect 11% of children worldwide (Fazel, Wheeler, & Danesh, 2005). World Food Programme (WFP) defines malnutrition as "a state in which the physical function of an individual is impaired to the point where he or she can no longer maintain adequate bodily performance process such as growth, pregnancy, lactation, physical work and, resisting and recovering from disease" (Programme, 2000).

A malnourished child, hence, experiences slow physical and cognitive development and stands a greater risk of morbidity and death than their normal counterparts (Fishman, De Onis, Blossner, Mullany, & Black, 2003; Programme, 2000). Poverty remains the major contributor to this poor health among children in sub-Saharan Africa. Traditional complementary foods are generally deficient in vital micronutrients as well as macronutrients (Eka, Abbey, & Akaninwor, 2010). Lack of education especially among women further disadvantages the vulnerable children in the delivery of healthy practices like breastfeeding and consumption of nutritious foods.

The promotion of local foods through nutrient evaluation and formulations is important when addressing malnutrition in low-income countries. The high cost of implementing programs that

provide fortified blended food supplements to malnourished children makes them unaffordable to poor countries (De Pee & Bloem, 2009).

As a result, our country depends on food aid for decades. So, it's important to adopt a horizontal approach in implementing programs at a community level, the sociocultural background of each community is, therefore, an essential baseline consideration for implementing nutrition health promotion programs. So, it's mandatory to develop various strategies for 'home' fortification, or point-of-use fortification, to ensure adequate micronutrient intakes by infants and young children. Ethiopia is among the poorest communities in the world. For decades, the Somali region is found in the eastern part of Ethiopia, and most of the food that is given to our children as complementary feeding depends on food aid from WFP and other UN development partners.

As a result, this study will put an effort to emphasize on use of a broad-based approach in the management of malnutrition in the Somali region. Formulations using local food materials were proposed as a means of averting nutrient deficiency among our young children.

Sorghum and peanut could be exploited since they are easy to access in the region. The product could be prepared at home and were used as complementary feeding for children under 06-23 years of age. Using the Opti food tool, a local food supplement was formulated from sorghum and peanut. The sensory acceptability of SBP for the children were analyzed for treatment of MAM in children below 2 years of age. Therefore, this study aims to analyze the Production and Evaluation of Proximate Composition and Sensory Properties of Sorghum Blended with peanuts (SBP) For Nutritional Improvement of Sorghum Foods.

1.3. Objectives

1.3.1. General objective

- The Production and Evaluation of Proximate Composition and Sensory Properties of Sorghum Blended with Peanut (SBP) For Nutritional Improvement of Sorghum Foods

1.3.2. Specific objectives

- To develop the recipe for sorghum blend peanut formation
- To analyze the Proximate composition of SBP product
- To analyze the Physico-chemical properties of SBP product
- To investigate the sensory qualities of SBP product
- To analyze the Anti-nutritional properties of SBP product
- To analyze the optimization of the blending ratio

1.4. Significance of the study

This study is so important as it is the 1st in its nature to conduct such a study on sorghum Variety and peanut and analyze their proximate composition, Physico-chemical properties, anti-nutritional factors, and sensory acceptability of the SBP products. The outcome of the study was important to get up-to-date data on the nutritional composition, and physical, functional, and anti-nutritional properties of the different sorghum varieties grown in SRS. The result obtained from this study were used to treat malnutrition among the infants in our region furthermore it was important for future researchers as baseline information to conduct their research. Based on the recommendation come out from this study, policymakers, government, non-government organizations and other interested institutions working in the area will expect to get up-to-date information from the study.

2. Literature Review

2.1. Origin, Description and Agro-Ecology of Sorghum

The crop sorghum originated in northeastern Africa, where large variability in wild and cultivated forms remains (FAO, 2014). It is a self-pollinating summer plant classified under the family Poaceae (grass family), tribe and Aropogoneae, species, Sorghum bicolor (L.) Moench. It is the fifth most important cereal crop in the world, after wheat, maize, rice and barley (Taylor, 2003)and the second major crop (after maize) across all agro-ecologies in Africa (Dahlberg, 2019; Dahlberg, Berenji, Sikora, & Latković, 2012). Domesticated in North Africa, possibly in the Nile or Ethiopian regions around 1000 BC. Its cultivation likely spread from Ethiopia, where it is believed domestication occurred, to Africa, the Middle East, and India along trade and shipping routes over 3,000 years ago (FAO, 2020).

Sorghum used as a source of food, feed, fiber and fuel and is one of the most important cereal crops grown in arid and semi-arid areas of the world, receiving 400 to 800 mm of rainfall annually (Maunder, 2002). Sorghum known under a variety of names: great millet and guinea corn in West Africa, kaffir corn in South Africa, durra in Sudan, Mtama in East Africa, johaalacholam in India and kaoliang in China. Cultivated sorghum divided into five groups namely bicolor, guinea, caudatum, kafir and dura. Sorghum varieties have used for many years for poultry and human consumption, especially in Africa and Asia, and have been shown to vary in physical and chemical characteristics (Gudu et al., 2013). Sorghum is cultivated as a major food crop in several countries in South Asia, Africa, and Central America. The crop is mainly growing in tropical and subtropical areas that are marginal and stress prone. Sorghum known as guinea-corn, dawa, or sorgho in West Africa, durra in the Sudan, Mashelia in Ethiopia and Eritrea, Mtama in East Africa, Kaffircorn, Mabele, or Amabele in southern Africa, and as jowar, jonna, cholam or jola in the Indian subcontinent. Sorghum is a major cereal crop in arid and semi-arid areas of the world.

It is a staple crop of semiarid sub-Saharan Africa. Sorghum is a major food and nutritional security crop to more than 100 million people in Eastern horn of Africa, owing to its resilience to drought and other production constraints (Mundia, Secchi, Akamani, & Wang, 2019). Sorghum is indigenous to Africa and accounts for 43% of all major food staples produced in sub-Saharan Africa considered sorghum as a traditional crop in much of Africa and Asia and an introduced and hybridized crop in the Western hemisphere (Tonapi et al., 2020). Sorghum (Sorghum bicolor) is

one of the most widely grown cereal crops in Ethiopia. It is a main food crop on which the lives of millions of poor Ethiopians depend. It has tremendous uses for the Ethiopian farmer and no part of this plant is ignored. Sorghum grows in a wide range of agro-ecologies most importantly in the moisture stressed parts where other crops can least survive and food insecurity is rampant. The primary and most important source of sorghum germplasm introduction for Ethiopia has been the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). From the very beginning of sorghum research in Ethiopia, a significant number of sorghum germplasm lines have been introduced from ICRISAT and evaluated annually for various desirable traits. The second most important source has been the International Sorghum and Millets (INTSORMIL) collaborative research support program (Adugna, 2007).

Sorghum used in various ways in our country; the grain is used for human foods such as injera, bread, porridge, Nifro, infant food, syrup, and local beverage known as "Tella" and "Arekie." In addition, the leaf and stalk used for animal feed, and further, the stalks used for the construction of houses and fences and as fuel wood (Xiong, Zhang, Warner, & Fang, 2019).

2.1.1. Common names of the crop

Common names of sorghum vary from continent to country levels. The most encountered names (ABRAHIM, Ahmed, & Belete, 2020) are: durra (Egypt), kafferkoren, soedangras, suikergierst, or suiker-sorghum (The Netherlands), kaoliang (China), mtatam, shallu orfeterita (East Africa), chicken corn, sorghum orguinea corn (United Kingdom), jola, jowar, jawa, cholam, bisinga, durra or shallu (India), kaffir corn (South Africa), milo, sorgo, Sudan grass sorghum (USA), milo (Middle East Africa) and great millet, guinea corn, feterita, sorghum or sorgho (West Africa). In the Sudan, this crop is named durra.

2.1.2. Uses of sorghum

Sorghum is grown in the United States, Australia, and other developed nations essentially for animal feed. However, in Africa and Asia the grain is used both for human nutrition and animal feed. It is estimated that more than 300 million people from developing countries essentially rely on sorghum as source of energy (Godwin & Gray, 2000). The main foods prepared with sorghumare: tortillas (Latin America), thin porridge, e.g. "bouillie" (Africa and Asia), stiff porridge, e.g. to (West Africa),couscous (Africa), injera (Ethiopia), nasha and kisra (Sudan),

traditional beers, e.g. dolo, tchapallo, pito, burukutu, etc. (Africa), ogi (Nigeria), baked products (USA, Japan, Africa), etc (Graham et al., 1986).

2.2. Importance of Complementary Foods

In developing countries, malnutrition persists as a principal health problem among children below the age of five (Fasasi, Adeyemi, & Fagbenro, 2007). The outcome of an infant's weight at birth and its survival depends on the state of nutrition of the mother before conception and throughout the gestation period (Ijarotimi, 2008). The growth and survival of a child continue after birth by deriving its nutrition through breastfeeding for the first six months of life. Especially in the first four months of age breast milk is adequate to provide the child with essential elements in balanced proportions and protect them against infections (M. Cameron, Hofvander, Y, 1983).

Recent studies have recognized the link between malnutrition and child feeding practices which showed that high numbers of children in developing countries are malnourished, and this has resulted in stunted growth, retardation in cognitive development, increase in morbidity and mortality rate (Ijarotimi, 2008). Complementary feeding is defined as the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of infants and therefore other foods and liquids are needed, along with breast milk (Organization, 2003).

Complementary foods are the traditional foods consumed between the time the diet consists exclusively of mother's milk and the time when it is mostly made up of family foods. Complementary food is also defined as those which are appropriately timed, nutritionally adequate, and hygienically prepared foods that are given to infants along with continued breastfeeding from six months of age. The target age range for complementary feeding is generally taken to be 6 to 24 months of age, even though breastfeeding may continue beyond two years. The energy needs from complementary foods for infants with "average" breast milk intake in developing countries are approximately 200Kcal/day at 6- 8 months of age, 300Kcal/day at 9-11 months of age, and 550Kcal per day at 12-23 months of age (Yeung, 1998).

2.3. Proximate composition of sorghum

2.3.1. Moisture content

From the moisture content analysis of four Sudanese sorghum genotypes and found the moisture content to range from 6.36 to 6.67%. The moisture content of two sorghum cultivars (African and Indian) was found to be 7.49% and 6.77% respectively (Mohammed, Ahmed, & Babiker, 2011). The moisture content of different cultivars of sorghum was reported between 8 and 12% (OLUWAFEMI). Generally, themoisture content varies according to the humidity, cultivar, area andenvironment, as claimed by, (Makawi, Mahmood, Hassan, & Ahmed, 2013).

2.3.2. Ash content

The ash content of food stuffs represents the inorganic residue remainingafter the organic matter has been burned. reported that the ash content of different cultivars of sorghum ranged between 1 and 4% (Marshall, 2010). found that the ash contents of two sorghum (Africanand Indian) cultivars were 2.29% and 1.54% respectively (Awadelkareem, Muralikrishna, El Tinay, & Mustafa, 2009). Another study about the ash content of four Sudanese sorghum genotype reported a range from 1.77% to 1.96% (Mohapatra, Tripathi, & Deshpande, 2017). The determined ash content of different cultivars of dura (sorghum), grown in different parts of Sudan, to range from 1.2 to 2.0% (Yagoub, Suleiman, & Abdel-Gadir, 2009).

2.3.3. Protein content

Also analysis of fifteen different cultivars of dura (sorghum) grown in different parts of Sudan, found that their protein ranged from 6.9 to 12.8% (Yagoub et al., 2009). The protein content of two cultivars of sorghum (African and Asian) was found to be 14.00 and 10.02% respectively (Awadelkareem et al., 2009). A report from the protein content of four Sudanese sorghum genotypes ranged from 12.24% to 13.67%. reported that the crude protein content of different cultivars of sorghum was between 7 and 15%. reported that the average protein content of sorghum varies according to a number of factors, including planting date, cultivars, seed size and temperature. The quality of protein is primarily a function of its essential amino acids composition; the function of dietary protein is to satisfy the body needs for nitrogen and essential amino acid (Gilani, Xiao, & Cockell, 2012).

2.3.4. Fiber content

The term dietary fiber was used to describe a variety of indigestible plant polysaccharides including cellulose, hemicellulose, pectin and various lignifiedcompounds. compared several sources of cereal fiber and found that sorghum bran was effective in lowering serum and liver cholesterol level in guinea pigs. reported the crude fiber content in fifteen different cultivars of dura (sorghum) grown indifferent parts of the Sudan, ranged from 1.4 to 2.6%. However, the fiber content in several sorghum cultivars was found to be between 1.2 and 6.6% (Stefoska-Needham, Beck, Johnson, & Tapsell, 2015).

2.3.5. Fat content

The lipids of sorghum are important nutritionally and also influence the flavor and storage characteristic of sorghum, (do Prado et al., 2019). studied fifteen different cultivarsof Dura (sorghum) grown in different parts of Sudan and found that the fat content ranged between 3.0 and 4.1%. reported that the fat content of different cultivars of sorghum were between 1.5 and 6.0%. fat content of twenty varieties of dura (sorghum) grown in different parts of Sudan ranged from 1.5 to 4.6% (GEOFFREY, 2013).

2.3.6. Carbohydrate content

Carbohydrate contents of fifteen different cultivars of dura (sorghum) grown in different parts of Sudan, were ranged from 72.4 to 78.7% (Yagoub et al., 2009). A report indicated the that the carbohydrate content of four sorghum genotypes ranged from 72.31 to 73.88%. reported that the carbohydrate contents of different cultivars of sorghumwere between 65 and 80% (Jimoh & Abdullahi, 2017).

2.3.7. Mineral content

The term mineral usually refers to elements other than C, H, O and Nthat are present in foods, these four non-mineral elements are present primarily in organic molecules and water, and constitute about 99% of the total numberof atoms living systems. Although minerals are normally found in relatively lowamount in food, their importance in this food is use known. The daily requirement of the elements of the calcium, and potassium was reported as follows: calcium (1000mg/day), Sodium (3000mg/day), Potassium (1500mg/day) and magnesium

(350mg/day) (Hasanudin, Hashim, & Mustafa, 2012).In the sorghum kernel the mineral matter is unevenly distributed and is more concentrated in the germ and the seed-coat (Sreeramaiah & Goudar, 2012). Minerals from plant sources, particularly those from plant seeds, are less bio accessible than those from animal source due to the phytic acid, tannin and fiber present in the plant (Mendoza, 2002). Bioavailability of minerals can be defined as the proportion of the total minerals in food meal or diet that is utilized for normal body function (metabolic processes) (Spears & Hansen, 2008).

2.3.8. Potassium content

found that total potassium contents in two cultivars of sorghum, African and Indian, were 225.23 and 367.51 mg/100g respectively. The potassium content of four sorghum cultivars ranged from 3.00 to 12.03% (Awadelkareem et al., 2009).

2.3.9. Calcium content

Calcium content in two cultivars of sorghum (African and Indian) was found to be 2.43 and 3.33%, respectively, (Awadelkareem et al., 2009). The calcium content of two cultivars of sorghum was found to be 9.34 and 75.7% respectively (B. Bean, Baumhardt, McCollum Iii, & McCuistion, 2013). Dickson, e reported that the calcium content of six cultivars of sorghum ranged from 5.2 to 38.1mg/100g (Ainebyona, 2021).

2.3.10. Magnesium content

A study from six cultivars of sorghum found that their magnesium content ranged between 109.8 and 224.1mg/100g (Fernandes et al., 2014). Magnesium content of four sorghum cultivars ranged between 2.12 to 4.81% was reported by (Yan et al., 2011). The magnesium content of four new sorghum lines was reported between 120 and 135mg/100g (Tasie & Gebreyes, 2020).

2.4. The Groundnut crops

2.4.1. Origin, Description and Agro-Ecology of Groundnut

The cultivated groundnut (Arachis hypogaea L.) is an ancient crop of the New World, which originated in South America (southern Bolivia/north west Argentina region) where it was cultivated as early as 1000 B.C. Dissemination of the crop to Africa, Asia, Europe and the Pacific

Islands occurred presumably in the sixteenth and seventeenth centuries with the discovery voyages of the Spanish, Portuguese, British and Dutch (Krapovickas, 1969, 1973; Gregory et al., 1980; Hammons, 1982; Isleib et al., 1994). Today, it is grown in areas between 40 degrees South and 40 degrees North of the equator, where average rainfall is 500 to 1200 mm and mean daily temperatures are higher than 20oC. The groundnut crop is cultivated in 108 countries on about 22.2 million hectares, of which 13.69 million ha are in Asia (India 8 million ha; China 3.84 million ha), 7.39 million ha in Sub-Saharan Africa, and 0.7 million ha in Central and South America. Average pod yields on a global scale increased slightly from 1.08 Mt ha-1 in the 1980's to 1.15 Mt ha-1 in the 1990's (Carley & Fletcher, 1995), and the global production is 29 million tonnes of pods. India, China, and the United States are the leading producers and grow about 70% of the world's groundnuts (FAO, 1995-2001; CGIAR Research, 2000).

2.4.2. UTILISATION

The uses of groundnut are diverse; all parts of the plant can be used. The nut (kernel) is a rich source of edible oil, containing 36 to 54% oil and 25 to 32% protein (Knauft & Ozias-Akins, 1995). About two thirds of world production is crushed for oil, which makes it an important oilseed crop (Woodroof, 1983). The oil is used primarily for cooking, manufacture of margarine, shortening and soaps. Seeds are consumed directly either raw or roasted, chopped in confectioneries, or ground into peanut butter. Young pods may be consumed as a vegetable while young leaves and tips are utilized as a cooked green vegetable (Martin & Ruberte, 1975). Scorched seeds may serve as a coffee substitute (Duke, 1981).

Nonfood products such as soaps, medicines, cosmetics, pharmaceuticals, emulsions for insect control, lubricants and fuel for diesel engines can be made from groundnut. The oil cake, a high-protein livestock feed, may be used for human consumption. The haulms are excellent high protein hay for horses and ruminant livestock. Groundnut shells may be used for fuel (fireplace "logs"), as a soil conditioner, for sweeping compounds, as a filler in cattle feed, as a raw source of organic chemicals, as an extender of resin, as a cork substitute, and in the building trade as blocks or hardboard (Gibbons, 1980).

2.4.3. Mineral contents of Groundnut

As indicated table 1, the elemental composition in which the predominant elements are potassium, sodium and phosphorus, contrary to Wen-Hesin et al. (1997) which gave the most predominant elements as potassium, phosphorus, magnesium and calcium. The most abundant mineral K is expected. The presence of calcium, magnesium, phosphorus, potassium and sodium are good indication that the groundnut is rich in the minerals for bone formation calcium is very essential in blood clothing muscles contraction and in certain enzymes in metabolic processes. Low Ca/P ratio facilitates calcinations of calcium in the bone while the Ca/P ratio above two helps to increase absorption of calcium in the small intestine. Also, Na/K ratio is very important in the body for prevention of high blood pressure. Na/K ratio less than one is recommended. The Na/K ratio in this work is about 0.06, which is indicative that the groundnut is very good for human health and would probably prevent high blood pressure.

Table 1. Mineral content of groundnut oil

Mineral	mg/100g
Na	42.00±0.71
K	705.11±0.86
Mg	3.98±0.04
Ca	2.28±1.94
Fe	6.97±1.62
Zn	3.20±0.11
P	10.55±0.68

2.5. Anti-nutritional factors

2.5.1. Tannins

Tannins are phenolic compounds that are commonly found in food such as grain, legumes and fruits and also, precipitate protein (Vuolo, Lima, & Junior, 2019). Tannin is any polyphenolic substances that have a molecular weight between 500 to 3000KD containing sufficiently large number of phenolic hydroxylic groups 100 to 200 M.W (Santos-Buelga & Scalbert, 2000). Phenolic compounds are classified into three groups: phenolic acid, flavonoids and tannin. Tannins are divided intotwo major classes hydrolysable tannins and condensed tannins. They are composed of a very diverse group of oligomers and polymers (Ashok & Upadhyaya, 2012). Hydrolysable tannins also known as tannic acid, consist of polyhydrex alcohol and glucose to which molecules of gallic or hexahydroxy diphonic acid (ellagic acid) are linked by ester bonds.

Condensed tannins are structurally more complex being polymers of the flavonoids flavan-3-ols (Reed, 1995). All sorghums contain phenolic acids and most contain flavonoids, but only brown sorghums contain condensed tannins (S. Bean et al., 2018).

2.5.2. Phytic acid

Phytic acid or phytate is widely distributed in mature cereal and legume grains. On the other hand, phytic acid is absent in bananas, onion, citrus, mushrooms and lettuce (Maga, 1982). It is primary present as a salt of mono- and divalent +cations (K^{+}, $Ca^{++}$and Mg^{++}). Biological roles suggested for phytic acid in seeds include, as a phosphorus store, as an energy store and possibly a mycological role in the field, preventing aflatoxin production in soy bean seeds making zinc unavailable to mold (Deshpande & CHERYAN, 1984). Phytic acid is a principal storage form of phosphate particularly in cereal grain (Kumar et al., 2021). Phytic acid is widely distributed in plants, especially in monocotyledon seed, mature legumes, cereal grains and oil seeds. Phytic acid represents a complex class of naturally occurring compounds that can significantly influence the functional and nutritional properties of foods. The structure and configuration of phytic acid make it highly reactive at different pH values, hence its chemistry is quite variable (Bora, 2014). Phytate may influence starch digestibility through interaction with amylase, proteinassociated with starch and calcium which catalyzes amylase activity(Yoon, Thompson, & Jenkins, 1983).

3. MATERIALS AND METHODS

3.1. Raw Materials

The experimental materials were obtained from the local market from Jigjiga city. Sorghum grains and peanut were collected about 5kg of the two samples.





3.1.1. Sample Preparation

3.1.1.1. Preparation of sorghum flour

Preparation of sorghum flour was done according to the method developed by(Almeida-Dominguez, Serna-Saldivar, Gomez, & Rooney, 1993). Five kg of sorghum grains were cleaned, sorted, small, broken and immature grain, dust, sand, stones, and other foreign materials were removed. The cleaned sorghum was washed with tape water and milled by portable hand machine after that it packed in airtight polythene plastic bags and stored at room temperature in dry place.

3.1.1.2. Preparation of Peanut flour

Preparation of peanut flour was done according to the method developed by (Arab, Helmy, & Bareh, 2010). Defective seeds (with holes) removed, de-hulled manually, milled, sieved and packed in airtight polythene bag, and stored at room temperature until it is needed for chemical analysis.

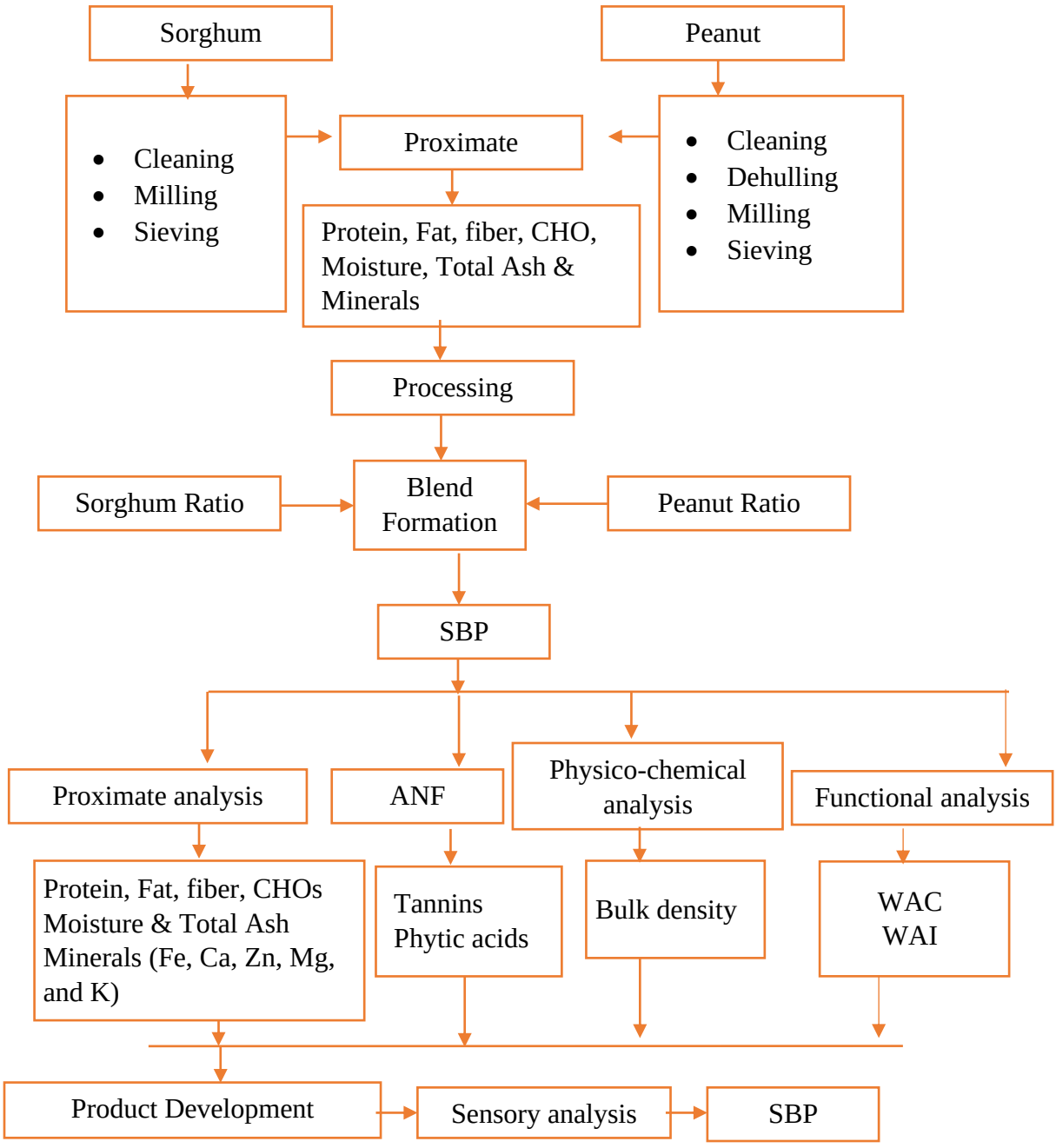


Figure 1. Flow diagram of experimental framework and preparation flour samples

3.1.2. Experimental design and formulation of composite flour

3.1.2.1. Experimental design

This study was carried out to find the appropriate ratio of sorghum, and peanut in composite flours for complementary foods. D-optimal mixture design with a total formulation of 7 (Table 2), which was obtained by inserting a range of sorghum 70-100g, and 0-30g was used to set up the experiment (Table 2). The range of thus ingredient was determined based on different literatures and trends in the study area (Mahgoub, 1999).Flour of the two basic ingredients was formulated by blending two of them using computer generating Design-Expert®, version 13. The simplex lattice design plot for the 2-components of mixture formulations (sorghum and peanut) was presented in table 3.

Table 2. Lower and upper limits of compost flours in mixture design

Ingredients	Lower limit	Upper limit
Sorghum	70	100
Peanut	0	30

3.1.2.2. Blending of sorghum based complementary food

Food formulation for infant and young children is undertaken using(M. Cameron & Hofvander, 1983) methods. In this experiment, a multi-mix infant formula was including two basics ingredients:

- Staple as the main ingredient (sorghum)
- Protein source from a (peanut)

In order to formulate CF, the primary criteria are to select ingredients that are rich in providing protein, energy and vitamin requirements of young children.

Table 3. Sorghum and Peanut blending ratio by using mixture D-optimum

Std	Run	A:Sorghum	B:Peanut
7	1	70	30
3	2	85	15
6	3	100	0
2	4	70	30
5	5	77.5	22.5
1	6	100	0
4	7	92.5	7.5

S:Sorghum, P:Peanut

3.1.3. Proximate Composition Analysis

3.1.3.1. Moisture content

Moisture contents of raw Sorghum flour and nixtamalized Sorghum flour samples were determined according to AOAC (2000), using the official method 925.05. The dishes used for the moisture determination were dried at 103^0C for 1 hour (Leicester, LE675FT, England) and placed in desiccators for about 30 minutes. The mass of each dish was measured (M_1) and weighed 5 g of the sample into each of the dishes (M_2). The sample dried at 103^0C for 6 hr. After drying, the mass of the sample and the container were measured (M_3). Calculated the moisture content from Eq. (1):

$$\text{Moisture content (\%)} = \left(\frac{W_2 - W_3}{W_2 - W_1}\right) \times 100 \qquad (1)$$

Where: M_1= mass of empty dish
M_2=mass of the empty dish plus mass of the sample before drying
M_3=mass of the empty dish plus mass of the sample after drying

3.1.3.2. Crude protein

According to AOAC method 979.09 (2000), the Kjeldahl method were used a semi-automatic (VELP SCIENTIFA nitrogen analyzer) to determine the crude protein. About 1.00 g of sample flour and 1.00 g of catalase mixture (10% copper (II) sulfate and 90 % potassium sulfate) to the Kjeldahl flask. Then 12 mL of concentrated sulfuric will add and placed in digesting track for one hour at a temperature of 420^0C until observed a clear solution. After digestion stopped and cooled, the sample will distill automatically by adding 50 mL of deionized water and 50 ml of 40% sodium hydroxide solution. Meanwhile, the titrated the distilled solution with about 0.2 N hydrochloric acids to a reddish color. Then the result was calculation as follows Eq. (2) and Eq. (3)

$$\text{Total nitrogen (\%)} = \frac{((V - V_b)xNx14)}{W} \qquad (2)$$

$$\text{Crude protein (\%)} = (\text{total nitrogen(\%)x6.25}) \qquad (3)$$

Where: V = volume of acid consumed to neutralize the sample
V_b= the volume of acid consumed to neutralize the blank
N = normality of the acid
W = weight of the sample.

3.1.3.3. Crude fat

Determined the crude fat analysis by using the Soxhlet extraction according to AOAC (2000) method 4.5.01, will weigh a milled sample (1.5 g), and were added it into a thimble. The thimble with the sample were placed in a 50ml beaker and dried in an oven for 2 hrs at 103±2^{o}C. the weighed a 150-250 ml dried cup and rinsed several times with petroleum ether. The sample contained in the thimble were extracted with petroleum ether in a Soxhlet extraction apparatus for 6-8 hrs. When the extraction completed, were placed the extracted fat into a pre-weighed beaker (mi). The cup with the extracted fat were allowed in a fume hood to evaporate the solvent on a steam bath until it became no odor. After that, the beaker with content were dried in an oven for 30 minutes at 103^{o}C. Finally, the cup with its contents were removed, cooled in a desiccator, and weighed its final weight (mf). After that, calculate the amount of fat in nixtamalized flours were calculated by using the following formula:

$$\text{Fat}(\%) = \left(\frac{m_f - m_i}{m}\right) \times 100 \qquad (4)$$

Where: mf = dried mass of fat with cup
mi = mass of the cup
m = weight of the sample

3.1.3.4. Crude fiber

Crude Fiber Content of the nixtamalized sorghum flour were determined according to AOAC (2000), using the official method 920.169. About 1.6 g weighed of the sample in each 600 mL beaker. 200 mL of 1.25% sulfuric acid solution were added to each beaker and allowed to boil for 30 minutes by rotating and stirring periodically. During boiling, the level will keep constant with the addition of hot distilled water. After 30 minutes, 20 mL of 28% potassium hydroxide solution will add to each beaker and allow to boil for another 30 min. The level will still keep constant with the addition of hot distilled water. Then after 30 minutes, the solution found in each of the beakers will filter through crucibles containing sand by placing each of them on a Buchner funnel fitted with a No.9 rubber stopper. During filtration, the washed sample with hot distilled water. Washed the final residue with 1% sulphuric acid solution, hot distilled water, 1% sodium hydroxide solution, and finally with acetone. Each crucible containing contents were dried for 2 hr at about 130^{0}C, cooled in desiccators, and weighed (M_1). Then, ashed for 30 min at 550^{0}C in a furnace and

cooled in desiccators. Finally, the mass of each crucible was considered (M_2). Calculated the crude fiber from Eq. (5).

$$\text{Crude fiber (\%)} = \left(\frac{M_2 - M_1}{W}\right) \times 100 \quad (5)$$

Where: M1 = the mass of the crucible, the sand, and the wet residue
M_2 = the mass of the crucible, the sand, and ash
W = sample weight dry matter basis

3.1.3.5. Total ash content

Total ash content was determined gravimetrically (AOAC, 2000) using the official method 941.12, by taking 3 g of samples in tared silica crucibles. The dried samples were slowly heated over a hot plate until the bulk of organic matter burnt. Then the crucibles were placed in a muffle furnace (SX-5-12, China) for ashing at 550^{o}C overnight to obtain carbon-free white ash. Calculated the ash content of the sample as given by Eq. (6).

$$\text{Ash}(\%) = \frac{\text{Weight of ash(g)}}{\text{Weight of sample(g)}} * 100 \quad (6)$$

3.1.3.6. Total Carbohydrate content

Determination of the carbohydrate content of sorghum flour samples by using the difference (Qamar et al., 2017; Ciabotti et al., 2016). The carbohydrate content estimated were subtracted from the moisture, fat, protein, fiber, and ash contents.

$$\%\text{CHO} = 100 - (\%\text{moistur} + \%\text{protein} + \%\text{fat} + \%\text{ash} + \%\text{fiber}) \quad (7)$$

Where: CHO = percentage of carbohydrate.

3.1.3.7. Energy content

Determination of energy content were obtained from multiplying the mean values of crude protein, utilizable carbohydrate, and crude fat by the factors of 4, 4, and 9, respectively. Then the sum of the products and the result were expressed in kilocalories per 100g (Kcal/100g) as reported by Atwater general factors system. The below formula shown were used for calculating energy.

$$\text{Energy(kcal/100g)} = 4 \times \%\ \text{protein} + 4 \times \%\ \text{carbohydrate} + 9 \times \%\ \text{fat} \quad (8)$$

3.1.4. Mineral Analysis

3.1.4.1. Calcium

Determination of calcium content by using an Atomic Absorption Spectrophotometer (AACC, 2000). Were Weighed 2g of sample into an ashing vessel and were pre-ignited at 550^{O}C and cooled in a desiccator. The sample were carbonized over a blue flame of Bunsen burner and put in the muffle furnace at 500^{O}C until the ashing end. Then, the ash will dissolve in 10 ml dilute 3 M HCl. The solution was boiled and evaporated nearly to dryness on a steam bath. The residue will re-dissolve quantitatively in 20 ml 2 M HCl and filtered through coarse porosity filter paper into a 100 ml volumetric flask. Washed the paper, and the residue were rinsed thoroughly with water and diluted to the 100 ml mark. Prepared standard solution (25 µg Ca/mL) from analytical grade $CaCO_3$ by dissolving 1.249 g in 30 ml HCl and 50 ml will distill the water and then diluted to 1 l. Finally, Calcium was measured by adding enough La stock solution to make the final dilution 1% La (i.e., 5 ml La solution to 25 ml flask, 20 ml to 100 ml flask), and added to the sample and final standard solutions (0, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 4.5 ppm, R^2 = 0.995). The absorbance of the sample will read with an Atomic Absorption spectrophotometer at 422.7 nm. Calculating the calcium content were used by the following formula:

$$\text{Ca (ppm)} = \frac{\text{C} \times 100}{\text{S}} \qquad (9)$$

Where: C = the concentration of the sample from a plot of absorption in µg/ml
S = weight of the sample

3.1.4.2. Iron

Determination of iron content by using an Atomic Absorption Spectrophotometer (AACC, 2000), weighed (2.0 g) of sample into the ashing vessel (pre-ignited at 550^{O}C and cooled in desiccators). Ashing at 500^{O}C, the ash was dissolved in a minimum volume of HCl-H_2O (1:1); 20 ml of this solution were added and evaporated to dryness on a steam bath. After cooling to ambient temperature, absorbance read at 248.3 nm. Using air-acetylene as a source of flame for atomization with Atomic Absorption standard solution (1000µg Fe/ml) prepared by dissolving 1.000g of pure iron wire in about 30 mL of 6M HCl with boiling and dilute 1 liter. Then the working range series

2,4,6,8,10,12,14,16,18, and 20 µg Fe/ml were prepared by dilution from the stock (1000µg Fe/ml). Iron content calculated with the following formula:

$$\text{Fe (ppm)} = \frac{(\mu g/mL)x100}{\text{Sample mass (DB)}} \quad (10)$$

Where: µg/mL is the absorbance reading concentration

3.1.4.3. Zinc

Determination of zinc content were conducted by using an Atomic Absorption Spectrophotometer (AACC, 2000), taking a sample (2.0 g) into the ashing vessel (that has been pre-ignited at 550^{o}C and cooled in desiccators). Ashing ended at 500^{o}C, and then the ash was dissolved in a minimum volume of HCl-H_2O (1:1); 20 ml of this solution were added and evaporated to dryness on a steam bath. After cooling to ambient temperature, absorbance read at 213.8 nm. Using air-acetylene as a source of flame for atomization with Atomic Absorption standard solution (1000 µg Zn/ml) was prepared from analytical grade Zn by dissolving 1.3830 g into 10 ml 6 M HCl and diluted to 1000 ml and 5 ml of the solution were taken and diluted to 500 ml mark with distilled water and a serious of standard solutions to construct the calibration curve 0.5,1,1.5,2,2.5,3,3.5,4,4.5, and 5 µg Zn/ml were prepared by dilution from the stock (1000µg Zn/ml). The following formula calculated zinc content:

$$\text{Zn (ppm)} = \frac{(\mu g/mL)\ x100}{\text{Sample mass (DB)}} \quad (12)$$

Where: µg/ml is the absorbance reading concentration

3.1.5. Functional Properties

3.1.5.1. Water absorption capacity

The WAC was determined according to the method described by Akubor (2005). One-gram sample was mixed with 10-mL distilled water (specific gravity 0.904 kg/m3) and allowed to stand at ambient temperature (31 ± 2^{o}C) for 30 min, and then centrifuged at 3,000 rpm for 30 min using centrifuge model 800-1D. WAC was determined by the following formula:

$$\text{WAC} = \frac{\text{Weight of water bound}}{\text{Weight of sample (dry basis)}} x100\% \quad (13)$$

3.1.5.2. Water absorption index

Water Absorption Index (WAI) was assessed as described by Anderson et al. (1969). Each flour sample of 3 g was suspended in 30 mL of distilled water in a tared 60-mL centrifuge tube. The slurry was stirred with a glass rod for 1 min at room temperature (25oC) and centrifuged (3000 × g, for10 min). The supernatant was eliminated. WAI was calculated from the weight of the remaining gel and expressed as g gel/g dry flour.

$$\text{WAI} = \frac{\text{weight of sediment (g)}}{\text{weight of sample (g)}} \qquad (14)$$

3.1.6. Determination of ant-nutrient properties of SBP flour

3.1.6.1. Tannins

Tannin content were determined according to the method described by Maxson and Rooney (1972), about 1.000g of the sample were weighed and mixed with 10 ml of 1% HCl solution in methanol in a screw cap test tube. Then the tube shaken were kept for 24 hr at room temperature on a mechanical shaker. The solution centrifuged were at 3000 rpm for 30 minutes. One ml of supernatant was transferred to another test tube and mixed with 5 ml of vanillin-HCl reagent (prepared by combining the equal volume of 8% concentrated HCl in methanol and 4% vanillin in methanol). D-catechin were used as a standard for condensed tannin determination. A 40mg of D catechin were weighted and dissolved in 100 ml of 1% HCl solution in methanol, which were used as stock solution. 0, 12, 24, 36, 48, and 60 ml of stock solution taken were in a test tube, and the volume of each test tube were adjusted to 1ml with 1% HCl in methanol. 5ml of vanillin-HCl reagent were added to each test tube. After 20 minutes, the absorbance of sample solutions was checked. The blank sample consisted of 1 ml of extract solution with 5 ml of 1 % HCl without vanillin-HCl reagent (+). Catechin standard at different concentrations (0.5-12 mg /100 ml) were used for the construction of the calibration curve. A standard curve (R^2 =0.993) will make from absorbance versus concentration, and the slope and intercept were used for calculation. The condensed tannin content was calculated by using the following formula:

$$\text{Tannin in mg/100g} = \frac{\text{Abso} - \text{Intercept}}{\text{Slope x Density x weight of the sample}} \qquad (15)$$

3.1.6.2. Phytate content

Determination of the phytate content were done by using the method described by Vantraub and Lapteva (1988). About 0.5 g of samples were extracted from 10 ml of 2.4% HCl in a mechanical shaker (Eberbach) for 1 hour at room temperature. The clear supernatant was used for phytate estimation. 1 ml of Wade reagent (containing 0.03% solution of $FeCl_3.6H_2O$ and 0.3% of sulfosalicylic acid in water) were added to 3 ml of the sample solution (supernatant). The mixture was in a vortex for 5 seconds to absorb the sample solutions at 500 nm using a UV-VIS spectrophotometer (Beckman DU-64- spectrophotometer, USA). 1 ml of the wade reagent were added to each test tube, and the solution were mixed on a Vortex mixer for 5 seconds. The mixture was centrifuged for 10 minutes, and the absorbance of the solution (both the sample and standard) were measured at 500 nm using deionized water as a blank. A standard curve was made from absorbance versus concentration, and the slope and intercept were used for calculation. Using the sodium salt of phytic acid as a standard for the construction of the calibration curve. Phytate content were calculated by using the following formula:

$$\text{Phytate in mg/100g} = \frac{\text{Abso} - \text{Intercept}}{\text{Slope x Density x weight of the sample}} \qquad (16)$$

.

3.2. Sensory analysis of SBP flour

Sensory evaluation of the SBP formulated from sorghum and peanut flour blended were carried out using 10 untrained panelists. The selection and screening of the panelists were based on the participant's interest to participate and evaluate the SBP. The participants were pre-informed about the evaluation and the purpose of assessing the sensory of the product. The sensory evaluation was done in a room with less noise and no other fragrance to avoid panelist disturbance and evaluated daylight brightness. Panelists were requested to test the SBP samples in appearance, aroma, taste, texture, and overall acceptance using a five-point hedonic scale. After evaluating each sample test panelist rinse their mouths with water in between two tests. Samples were evaluated based on five Point hedonic scales (1, dislike very much; 5, like very much) for one attribute.

3.3. Data analysis and Optimization

All the analyses were performed in duplicates (unless stated otherwise) and presented as mean. The statistical significance of the data obtained will be analyzed and modeled using Design expert ® version 13. The level of significance was accepted at probability ($p \leq 0.01$ and 0.05).

4. RESULTS AND DISCUSSION

4.1. Functional properties of SBP flour

The functional properties (bulk density, water absorption capacity and oil absorption capacity) of composite flour with the individual ingredients were summarized in table 4. Analysis of variance results is also summarized in appendix table 10. Models for functional properties were fitted indicated that the lack-of-fit p-values were not significantly different at 5% probability level or ($P<0.05$). Diagnostic tools like normality plot of residuals indicated that the residuals of all the response variables are normally distributed.

Table 4. Functional properties of SBP flour samples

Std	Run	Block	SBP		Functional properties		
			A:	B:			
			Sorghum (g)	Peanut (g)	Bulk Density (g/ml)	Water Absorption Capacity (%)	Water Absorption Index (g)
7	1	Block 1	70	30	0.68	133.95	3.71
3	4	Block 1	85	15	0.62	131.17	3.68
6	3	Block 1	100	0	0.59	128.46	3.63
2	2	Block 1	70	30	0.67	133.96	3.72
5	5	Block 1	77.5	22.5	0.63	132.99	3.70
1	6	Block 1	100	0	0.60	128.15	3.62
4	7	Block 1	92.5	7.5	0.61	129.97	3.65

SBP= Sorghum Blended peanut, A= Sorghum, B= Peanut

4.1.1. Bulk Density

Table 3 indicates that the sorghum blended with peanut flour have a high significant effect ($P\leq0.01$) on the bulk density. The functional properties of the bulk density were ranged between 0.59 to 0.68 g/ml(Table 4). The bulk density found in this study was lower than the results reported by(Alemayehu, 2014), who reported a bulk density of between 0.81-0.84 g/ml.

As seen from the figure 1, the bulk density of SBP flour samples showed an increasing trend with the increment of the proportion of sorghum and peanut flour. This result agrees with Masood and (Butt & Rizwana, 2010) indicated that the bulk density was increased in the composite flour with soybean protein content. Similar results reported by (Malomo, Eleyinmi, & Fashakin, 2011) who indicated that bulk density of composite flour of yam with soybean increased as the amount of soybean increased. High energy foods have low density and high-density foods low energy, and the results of this study may be observed due to the protein and fat content found in peanut flour

was higher compared to sorghum ration. The low bulk density of the blends is an advantage in the formulation of complementary foods (Akubor & Ukwuru, 2003). The regression model for bulk density was shown by (Eq. 17) indicating in quadratic model with two variables.

$$Y = 0.67_{x_1} + 0.59_{x_2} - 0.06_{x_1x_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .. \text{eq. } 17$$

Where Y= Bulk density, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

Figure 2 shows that the bulk density of the two-component mixture increased as the peanut ratio decreases, and the bulk density increases. This trend agrees with the observed result (Isah, Danladi, & Ejike, 2013) reported, who noted that the bulk density of complementary food increases as the maize flour blends increase, the maize flour is higher in bulk density than the soybean flour .

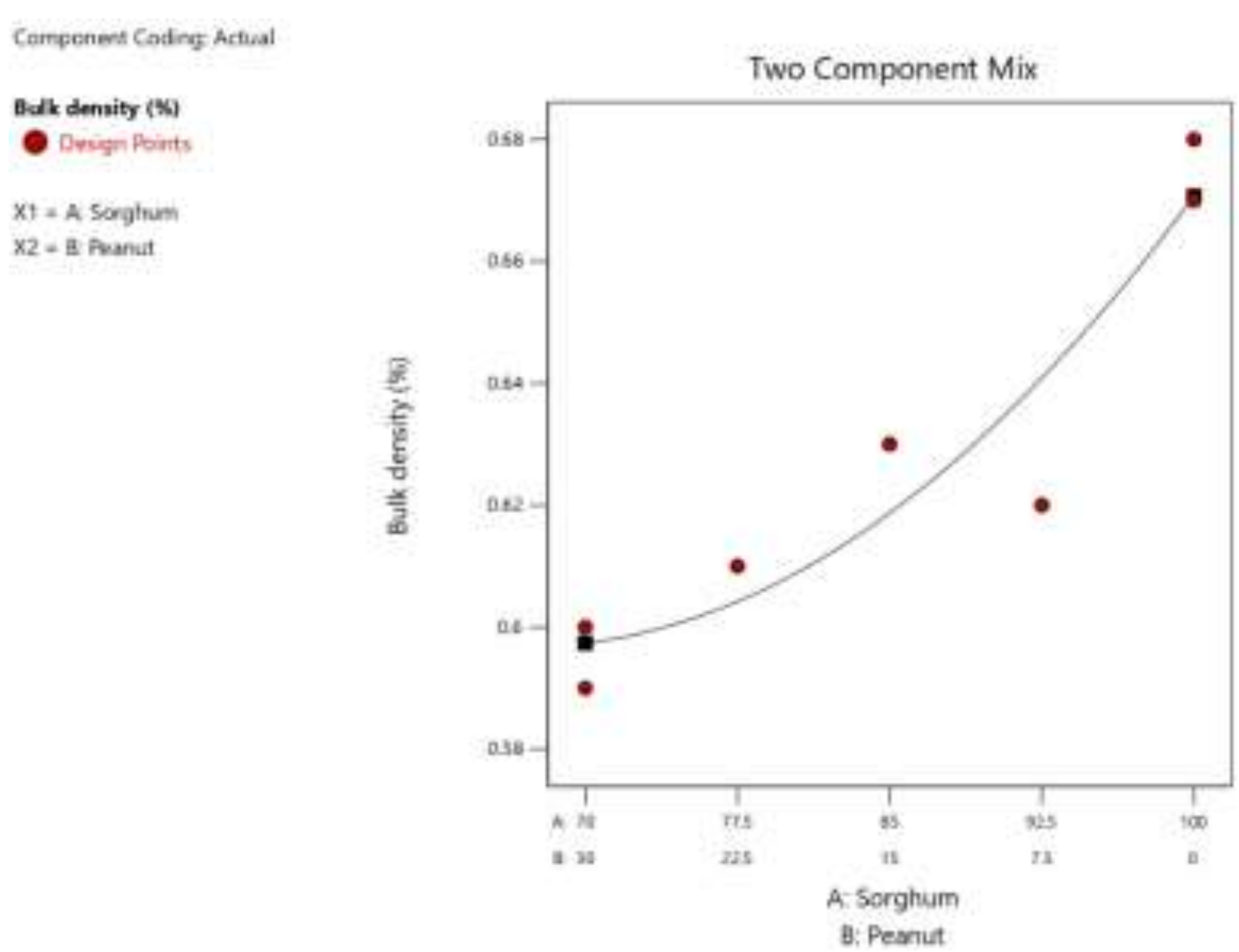


Figure 2. Contour line showing the bulk density while the black points show the treatment formulations of the SBP flour

4.1.2. Water absorption capacity

Water absorption capacity is a measure of how much water is needed to create gruel that is the right consistency for feeding newborns. Water absorption capacity is determined by the availability of hydrophilic groups to bind water molecules and the ability of macromolecules to form gels (Onweluzo & Nwabugwu, 2009). Water absorption capacity gives an indication of the amount of water available for gelatinization. The water absorption capacity(WAC) of the present study, the composite flour was varied between 128.15-133.96% (Table 4).

As indicated in (appendix table 10), the results shows that the mixture proportions of the sorghum and peanut have a strong linear significance ($P \leq 0.01$)effect on the water absorption capacity. The highest WAC of the sorghum in enriched with peanut flour was 133.96% at 70 grams of sorghum with 30 gram of peanut flour while the lowest percent recorded was 128.15% at 100 grams of sorghum with 0 gram of peanut flour. As indicated in figure 3, the trend increases WAC in the blended formulations, and this might be due to the higher protein content in peanut flour. Low water absorption values show mostly intact starch granules, but high values are attributed to protein denaturation, starch gelatinization, and crude fiber swelling. Damaged/transformed starches have a high-water absorption capacity and can produce paste at room temperature via the gelatinization mechanism (Nwabueze, 2006). The regression model for WAC was shown by (Eq. 18) indicating in quadratic model with two variables.

$$Y = 128.30_{x_1} + 134.01_{x_2} + 0.94_{x_1x_2} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \text{eq. } 18$$

Where Y= Water absorption capacity, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

According to figure 2, the Contour line indicates that WAC increased as the proportion of the peanut flour increased and these results indicated that peanut has high protein contents and Protein has both hydrophilic and hydrophobic properties, and so can interact with water in foods and peanut has high fat contents which can results increases of the WAC. This result agrees with the study reported by (Karim, Oyeyinka, Kayode, Ogunjobi, & Ibrahim, 2014), the results indicated that WAC of Maize flour increases when blended with groundnut. According to the result of this study, peanut and soybean have hi gh content of protein and fat than sorghum, and this can lower hydration capacity of the sorghum (Mbata, Ikenebomeh, & Ezeibe, 2009).

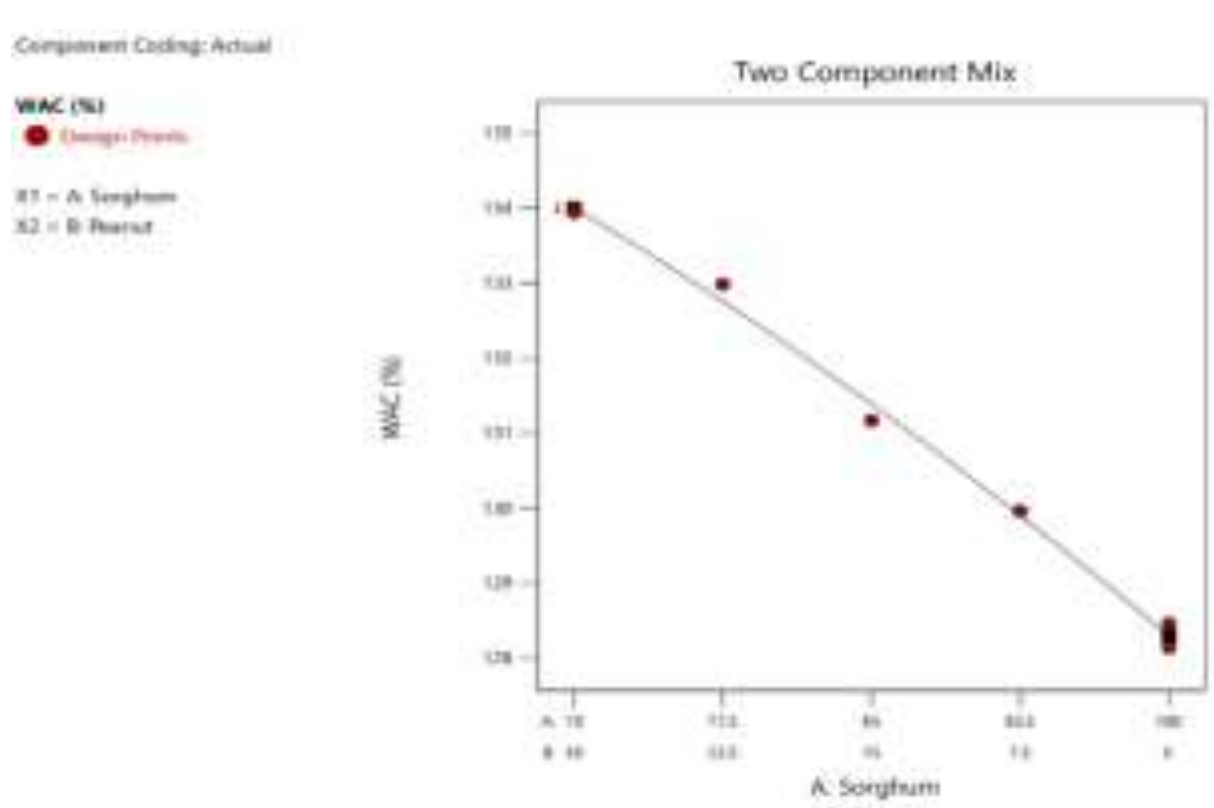


Figure 3. Contour line showing the water absorption capacity while the black points show the treatment formulations of the SBP flour

4.1.3. Water absorption Index

As indicated appendix table 10, the mixture proportion of the sorghum and peanut flour have strong linear significance ($P \leq 0.01$) on the water absorption index (WAI). The WAI measures the volume occupied by a substance after swelling in excess of water. Table 4 shows that WAI of the SBP sample flour, increases of the proportion of the peanut increases the WAI of sorghum. The highest WAI was seen in run-1, and run-2, 70g of sorghum with 30g of peanut respectively. Also, lowest WAI was seen in run- 3 and run-6, 100 grams of sorghum with 0 gram of peanut respectively.

The WAI of this study has similar results with previous studies on extruded sorghum and legumes (Pelembe, Erasmus, & Taylor, 2002). This increase was probably due to some gelatinization of the starches which would increase the availability of hydrophilic groups in the food system and due to the increased gel-forming capacities of other macromolecules, such as dietary fiber and proteins (Andersson & Hedlund, 1990). From the figure 3, the curve line indicates that WAI increased as the peanut flour increased. The regression model for WAI was shown by (Eq. 19) indicating in quadratic model with two variables

$$Y = 3.62_{x_1} + 3.72_{x_2} + 0.02_{x_1x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{eq. } 19$$

Where Y= Water absorption index, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

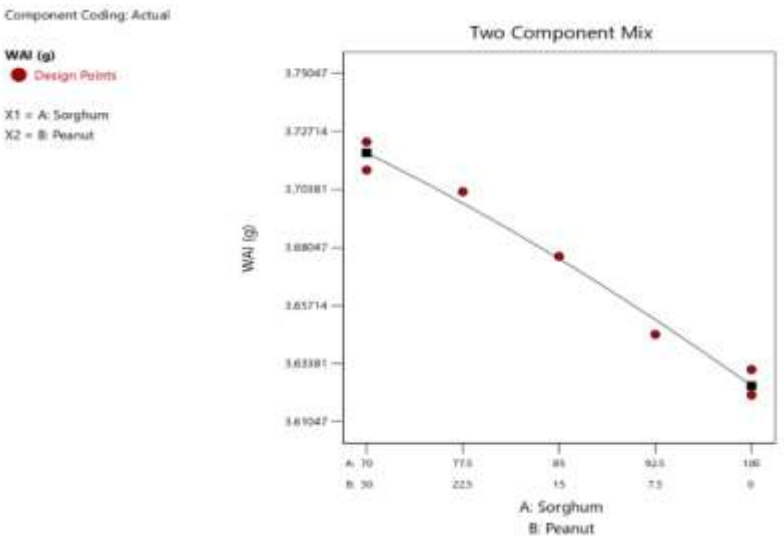


Figure 4. Contour line showing the water absorption index while the black points show the treatment formulations of the SBP flour

4.2. Proximate composition and energy content of SBP flour

Table 6 indicates the proximate composition (moisture, ash, crude protein, crude fat, crude fiber, carbohydrate and Energy content) of porridge flour from the local ingredients of sorghum and peanut. As indicated the appendix table 11, models for all proximate compositions were fitted indicated that the lack of fit p-values were not significantly different (P<0.05). Diagnostic tools like normality plot of residuals indicated that the residuals of all the response variables are normally distributed. The results of the chemical composition analysis of the raw materials of sorghum and peanut were presented in table 5. Components other than moisture contents are expressed on dry basis. There was a significance (P<0.01)difference between the difference in the values of moisture, protein, fat, ash, fiber, carbohydrate and energy contents.

Table 5. Proximate composition of SBP flour samples

Std	Run	Block	SBP		Proximate composition						
			A:	B:							
			Sorghum (g)	Peanut (g)	M.C (%)	C.P (%)	C.fat (%)	C.Fib (%)	Ash (%)	CHO (%)	Energy (kcal/100g)
7	1	Block 1	70	30	6.35	17.38	14.60	3.61	3.98	54.08	417.27
3	4	Block 1	85	15	5.75	14.70	10.52	2.84	1.98	64.21	410.32
6	3	Block 1	100	0	5.34	12.53	4.40	1.05	1.34	75.33	391.09
2	2	Block 1	70	30	6.23	16.46	15.61	3.53	3.8	54.37	423.80
5	5	Block 1	77.5	22.5	6.09	15.65	12.50	2.97	2.61	60.17	415.83
1	6	Block 1	100	0	5.41	12.43	4.42	1.59	1.32	74.83	388.86
4	7	Block 1	92.5	7.5	5.67	13.66	7.71	2.73	1.45	68.78	399.14

SBP= Sorghum Blended peanut, A= Sorghum, B= Peanut, MC=Moisture Content, C.P=Crude Protein, C.Fib= Crude fiber, CHO=Carbohydrate, kcal=kilo calorie.

4.2.1. Moisture content

As indicated appendix table 11, finding of the study from the mixture proportion of the sorghum and peanut flour have strong linear significance at 1% probability level or (P≤ 0.01) on the moisture content of SBP flour. The moisture content of the SBP sample flour were ranged between 5.34 to 6.35%. also the mixture proportion of 70 grams of sorghum and 30 gram of peanut had the highest moisture contents compared to the other ratios of the mixture and these results indicated that increasing peanut ratio is increases the moisture content of the sample flours of the mixtures. According the FAO/WHO recommendation on the safety limit of the microbial prevention of the soft products like porridge, the results of this study indicates that the SBP product has desirable moisture content of 6.35% of the highest compared to the FAO/WHO recommended safe limit

below (<10%). High moisture content in foods has been shown to encourage microbial growth (Temple, Badamosi, Ladeji, & Solomon, 1996). This is an important consideration in local feeding methods in developing countries because most mothers often prepare large quantities of dry infant foods and keep in containers, to avoid frequent processing in order to have spare time and energy for other domestic activities (Makinde & Lapido, 2012). The regression model for moisture was shown by (Eq. 20) indicating in quadratic model with two variables

$$Y = 5.39_{x_1} + 6.29_{x_2} - 0.05_{x_1 x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. \text{eq. } 20$$

Where Y= Moisture content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

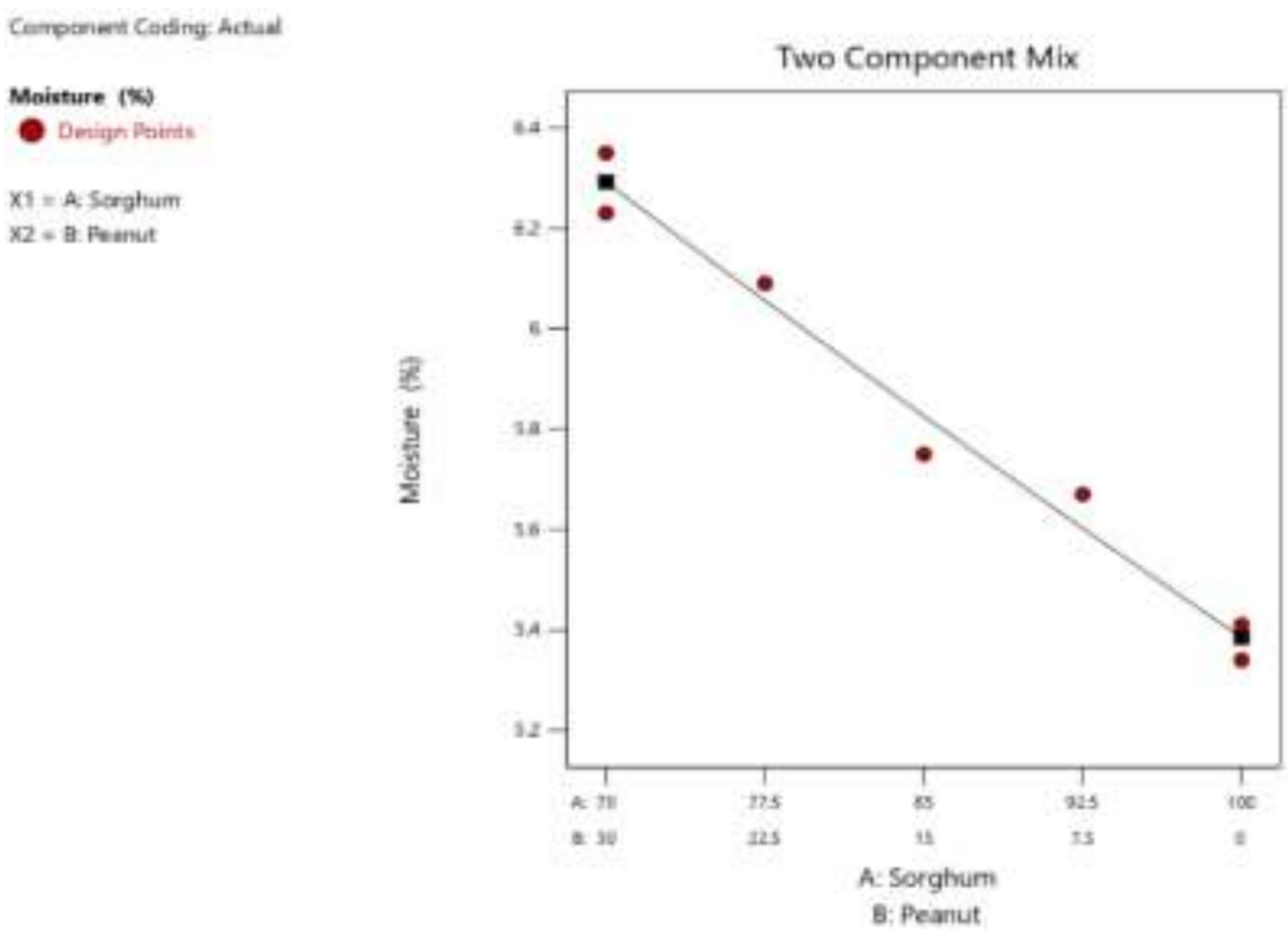


Figure 5. Contour line showing the Moisture content while the black points show the treatment formulations of the SBP flour.

4.2.2. Protein contents

Appendix table 11 shows that the linear mixture of the sorghum enriched with peanut flour has a strong linear significance (P≤ 0.01) effect on the protein content of the SBP sample flours. As indicated in table 5, the result indicates that the crude protein content of the SBP samples were ranged between 12.53 to 17.38% of protein concentration. the highest protein (17.38%) content was observed from the ratio of 70 gram of sorghum and 30 gram of peanut flour which assumed to be promising potential as a good source of plant protein. The protein contents of this study are in line with (Teshome, 2014). The results indicated that the protein contents of non-extruded protein of were ranged between 11.17 to 16.38% of protein concentration. As seen in figure 6, the curve line indicated that increasing the peanut ration results high protein contents and decreasing the peanut ratio results in declining the curve into the lowest protein concentration.

A minimum protein content of 15% is required for maximum complementation of amino acids in foods and for growth. Thus all the above formulations whose protein value contain 15% and above were satisfied the protein demand for complementary foods for older infants and young children according to (SESSION, DU COMITÉ, & LES HUILES, 2015).

The regression model for crude protein content was shown by (Eq. 21) indicating in quadratic model with two variables.

$$Y = 12.50_{x_1} + 16.89_{x_2} - 0.11_{x_1 x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. \text{eq. } 21$$

Where Y= Protein content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

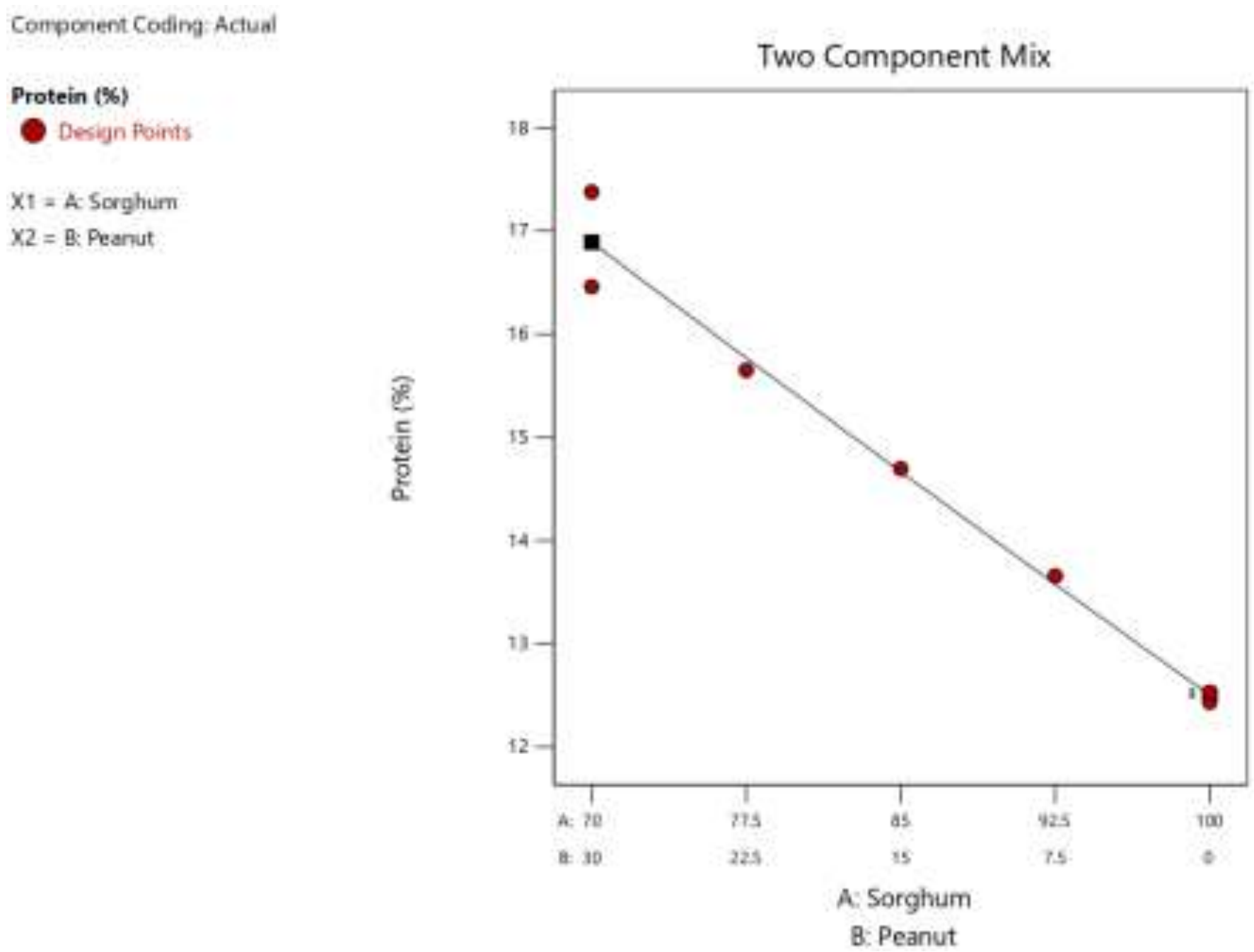


Figure 6. Contour line showing the Protein content while the black points show the treatment formulations of the SBP flour

4.2.3. Crude fat contents

Appendix table 11 shows that the linear mixture of the sorghum and peanut flour has a strong linear significance ($P \leq 0.01$) effect on the crude fat content of the SBP sample flours. The crude fat content of sorghum and peanut flour recorded in this study was found in between the values 4.40-15.61% . also this study has similar results with study conducted by (Teshome, 2014), the results showed that the fat contents result of the extruded blends of sorghum- peanut, sorghum-soya bean and local control samples. The results were ranged between (7.3-I8.36%), (4.42-, 10.5%) and (1.25%) for extruded sorghum-peanut, extruded sorghum, soya bean and control

samples respectively. Also other similar result was reported by (Shimelis & Rakshit, 2005). On the other hand the higher crude fat content of sorghum flour (4.12%) was reported by (Makinde & Lapido, 2012). This variation may be occurring due to the variety and/or processing effects. The regression model for crude fat content was shown by (Eq. 22) indicating in quadratic model with two variables.

$$Y = 4.46_{x_1} + 15.03_{x_2} + 2.48_{x_1 x_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. \text{eq. } 22$$

Where Y= Crude fat content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

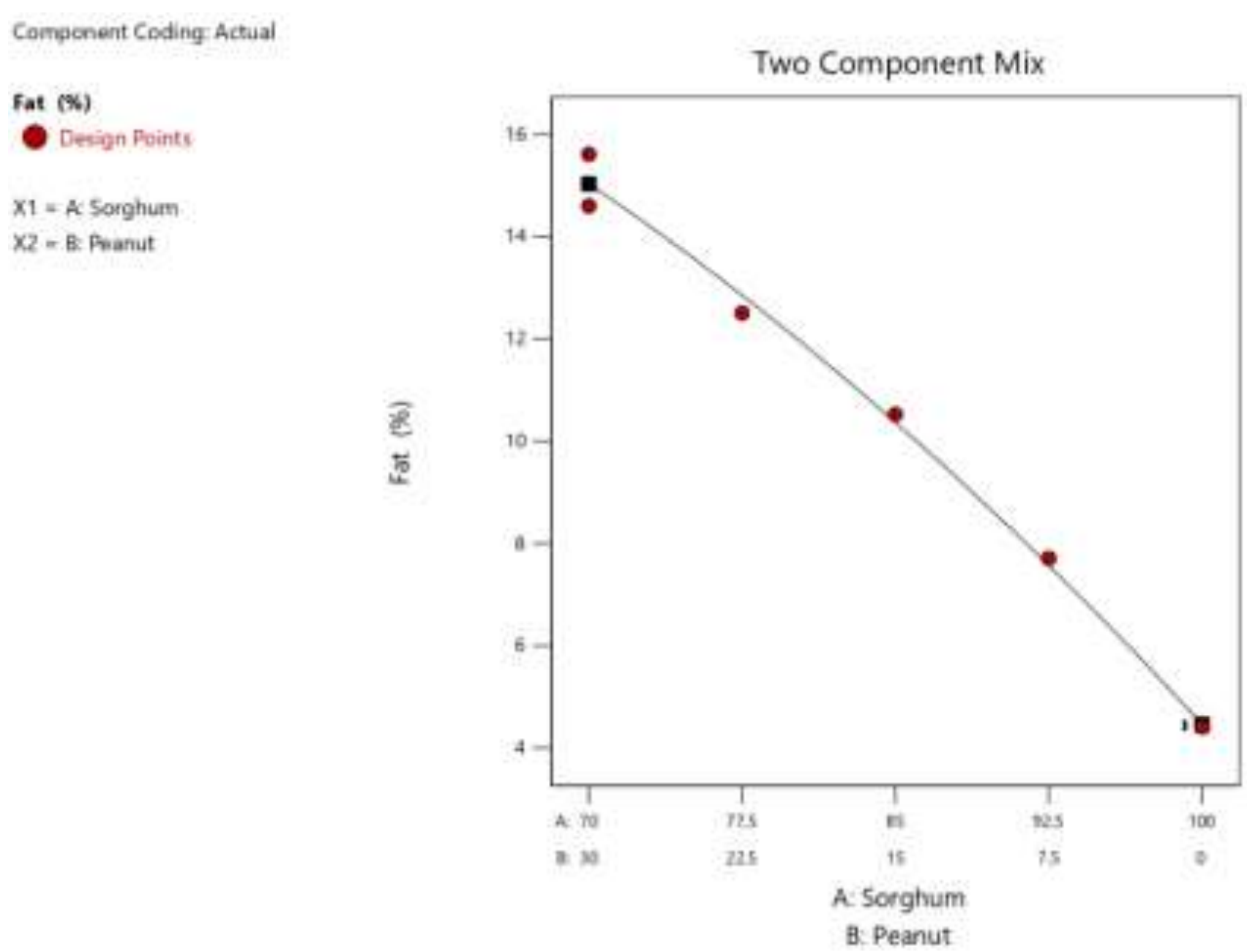


Figure 7. Contour line showing the Fat content while the black points show the treatment formulations of the SBP flour

4.2.4. Crude fiber contents

Appendix table 11 shows that the linear mixture of the sorghum and peanut flour has a strong linear significance ($P \leq 0.01$) effect on the crude fiber content of the SBP sample flours. The fiber content of SBP samples from seven different formulations was varied between 1.05 to 3.61% (Table 5). There was a statistically significant difference ($P \leq 0.01$) between different composite SBP sample flours. The higher fiber content was observed in SBP samples prepared from 70 grams of sorghum and 30 grams of peanut flour. The results also indicated that the fiber contents of the SBP samples showed an increase trend with parallel increase in the proportion of the peanut flours. This result was in agreement with finding (Teshome, 2014), The fiber content was ranged between

(1.3 1-2.29%),(1.28-2. 18%) and (2.28 %) for sorghum peanut, sorghum-soya bean and the control samples respectively.

Acceptable fiber content of weaning foods should not exceed 5% according to the Protein Advisory Group Recommendations (1972). When the fiber content is high it decreases the digestibility of the particular food. The crude fiber contents of the sorghum-peanut were within an acceptable range. The amount of fiber content was shown in mixture contour graph (Figure 8) and the regression model for crude fat was shown as (Eq. 23) indicating quadratic model with two variables.

$$Y = 1.42_{x_1} + 3.48_{x_2} + 1.87_{x_1x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{eq. } 23$$

Where Y= Crude fiber content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

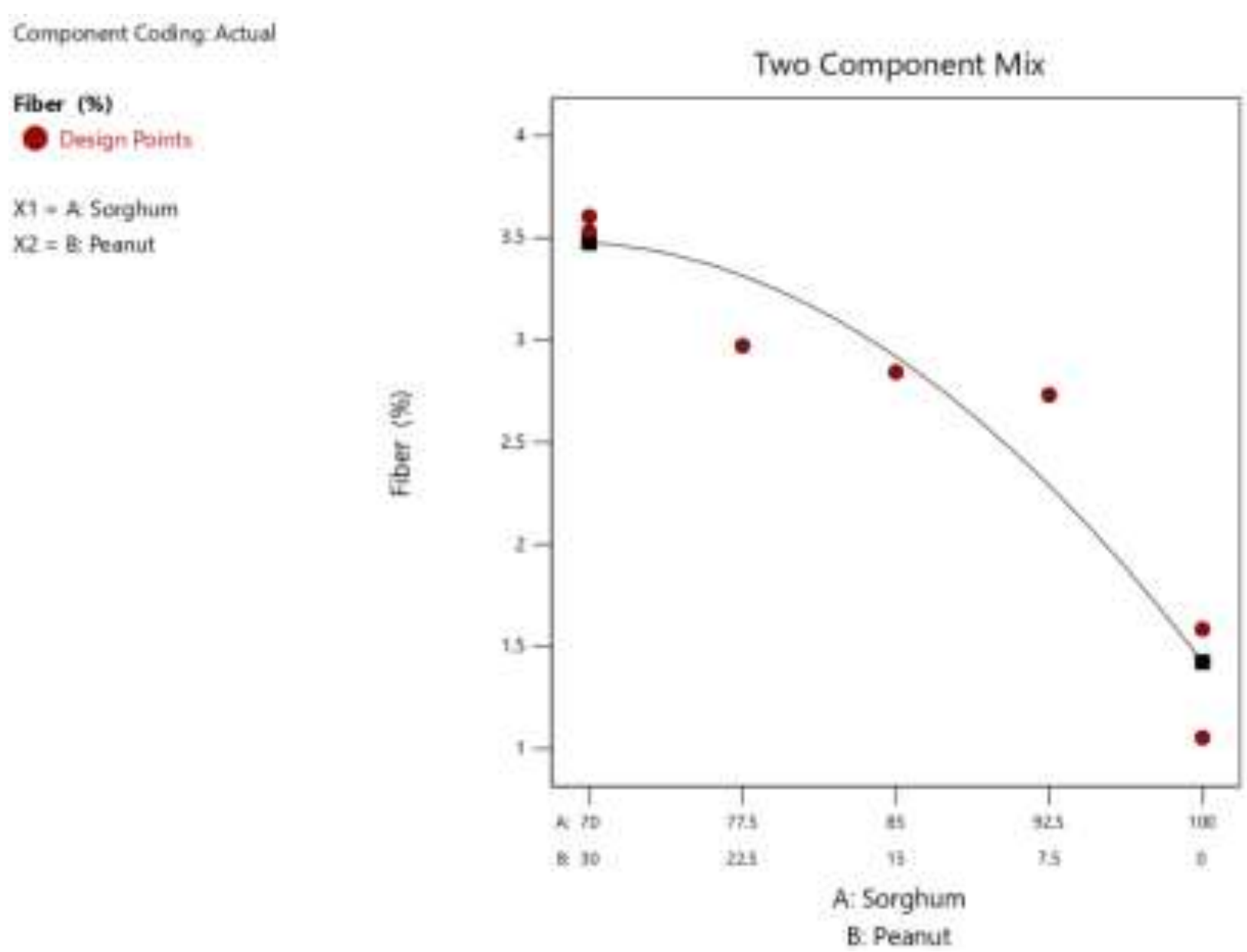


Figure 8. Contour line showing the fiber content while the black points show the treatment formulations of the SBP flour.

4.2.5. Total ash contents

Appendix table 11 shows that the linear mixture of the sorghum and peanut flour has a strong linear significance ($P \leq 0.01$) effect on the total ash content of the SBP sample flours. The ash contents result of the SBP blends of sorghum-peanut samples shown on(Table 6) were ranged between 1.32 to 3.98%. This result agrees with study report by (Teshome, 2014), The ash contents

result of the porridge blends from sorghum-peanut, sorghum-soya bean and the control samples were ranged between(1.33- 1.91%), (1.87-3. 19%) and (1.1 0%) respectively.

Acceptable ash content of weaning foods which given by the Protein Advisory Group recommendations (1972) should not exceed 5%. The result of sorghum ash content was similar to the report by(Makinde & Lapido, 2012) in their study of the physico-chemical properties of sorghum based complementary food. Formulated foods studied in the current study were within this limit as well (Munasinghe, Silva, Jayarathne, & Sarananda, 2013). The highest value of ash content recorded indicates that SBP flour has a good potential to prepare a CF that supports mineral requirement of the infants' complementary feeding period. The regression model for crude fat content was shown by (Eq. 24) indicating in quadratic model with two variables.

$$Y = 1.42_{x_1} + 3.48_{x_2} + 1.87_{x_1 x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. \text{eq. } 24$$

Where Y= Total ash content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

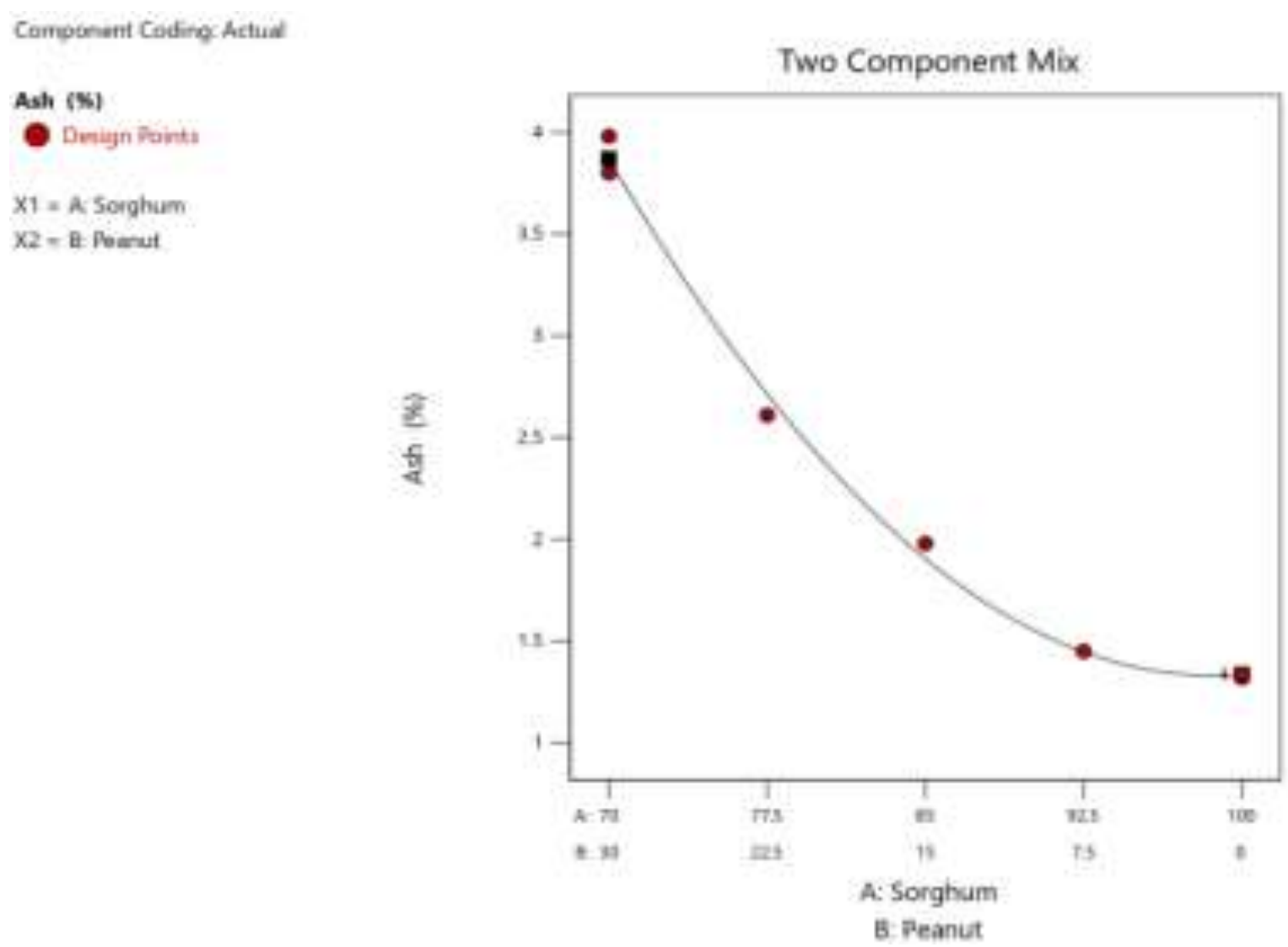


Figure 9. Contour line showing the total ash content while the black points show the treatment formulations of the SBP flour

4.2.6. Total Carbohydrate content

As shown in appendix table 11 the linear terms of the mixture from the sorghum and peanut flour have a strong significance (P≤0.01)on the total carbohydrate content. The total carbohydrate content ranged from 54.08% to 75.33% for all the formulations (Table 5). According to the finding

of the study sorghum with zero peanut ration was indicated the highest carbohydrate contents and lowest carbohydrate contents was seen with peanut ration of 30 gram. As the number of peanuts in the formulation increased, the carbohydrate content of the raw blends reduced significantly ($p<0.05$ due to the peanut's lower carbohydrate content. This decrease in the lower total carbohydrate content could be attributed to the lower carbohydrate content in peanut flours. This study also in line with the study reported by (Teshome, 2014), the total carbohydrate content decreases due to the lower content of carbohydrate in peanut and soybean. According to the protein advisory group (1972), sorghum was used as the main carbohydrate supplier which help to maintain 65% of the carbohydrate contents. The regression model for crude fat content was shown by (Eq. 25) indicating in quadratic model with two variables.

$$Y = 74.89_{x_1} + 54.44_{x_2} - 1.38_{x_1x_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. \text{eq. } 25$$

Where Y= Total Carbohydrate content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

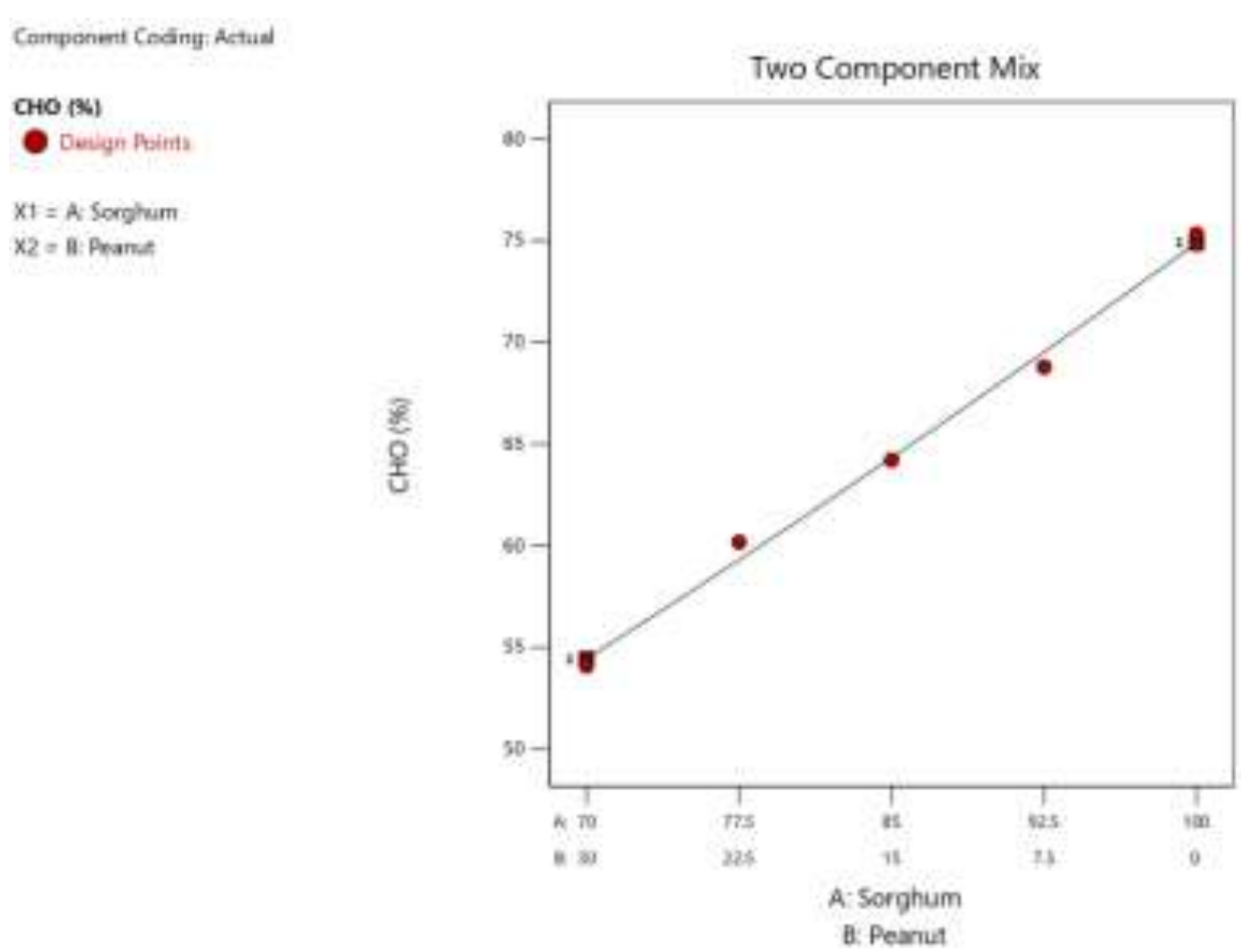


Figure 10. Contour line showing the total carbohydrate content while the black points show the treatment formulations of the SBP flour.

As indicated figure 10, the curve of the graph shown that the carbohydrate content increases the as the peanut ration decreases. The carbohydrate content of sorghum flour obtained in this study was comparable with reported 74.68% by (Mohammed et al., 2011). While lower than the value 76.94 % reported by (Shimelis & Rakshit, 2005). This variation may be due to the germination time and variety with different experimental condition respectively.

4.2.7. Total Energy content

As indicated in appendix table 11, the linear model of the mixture from the sorghum and peanut flour has strong significance ($P \leq 0.01$) on the gross energy content. The total energy content of sorghum flour, and peanut flour was shown in (Table 5). The total energy content of SBP sample flours were varied from 388.86% to 423.80 kcal/100g. The higher total energy content was observed in the SBP sample prepared from a formula sorghum 70 gram, and peanut 30 gram and the lower energy content was observed in SBP sample prepared from a formula sorghum 100 gram. As a result, this result suggested that the high protein and fat content of peanuts may be responsible for the SBP samples' high calorie content when they are made using a large amount of peanut flour. The study on complementary food characteristics found that the high-fat content of legumes and oil crop flour further boosted the energy density of the products prepared from various formulas (Onabanjo, Akinyemi, & Agbon, 2009). The regression model for total energy content was shown by (Eq.26) as indicated in quadratic model with two variables

$$Y = 389.73_{x_1} + 420.60_{x_2} + 16.27_{x_1 x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. eq. 26$$

Where Y= Total Energy content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

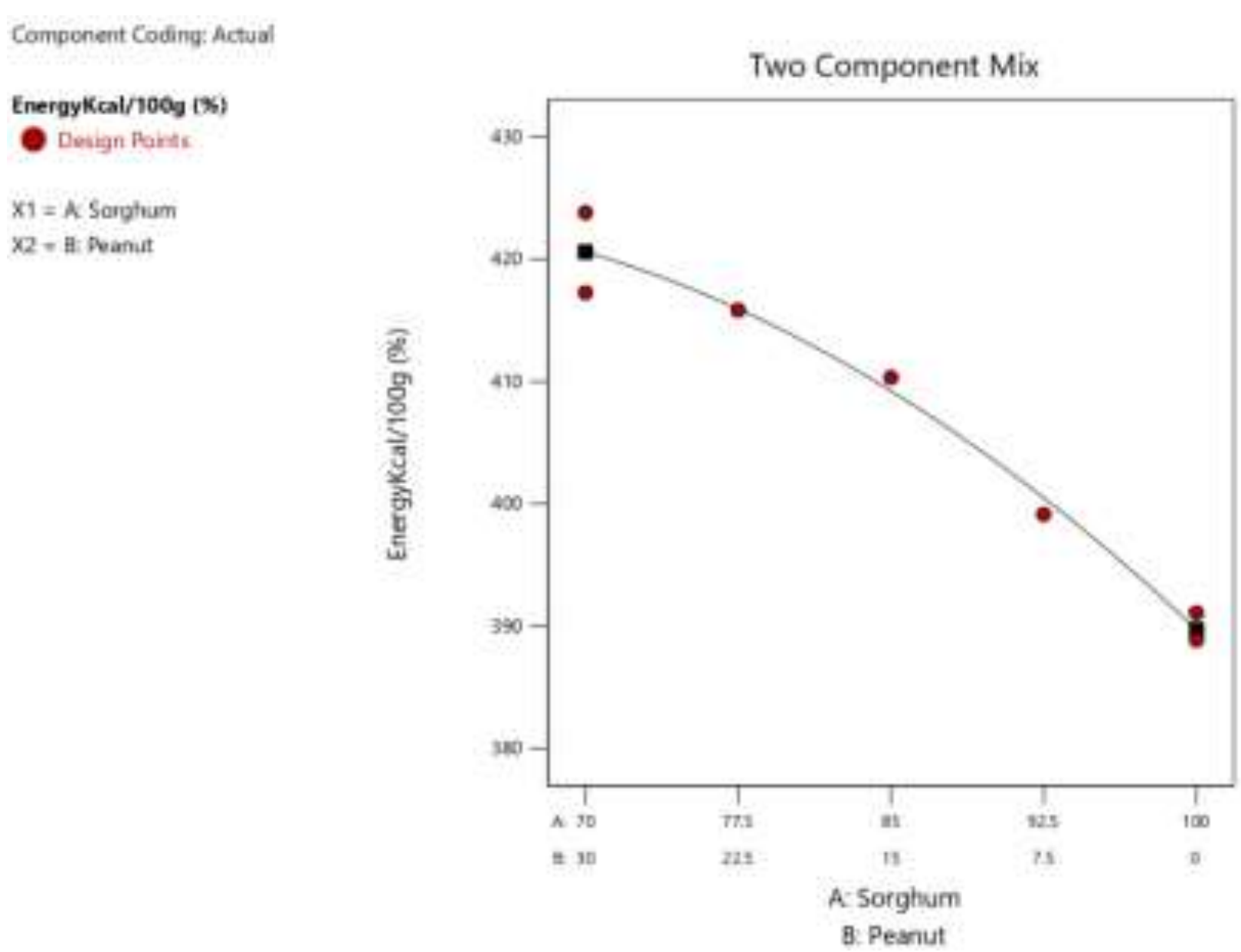


Figure 11. Contour line showing the total energy content while the black points show the treatment formulations of the SBP flour

The current total energy requirement estimated for healthy breastfed infants is of approximately 615 kcal/day from 6 to 8 months of life, 686 kcal/day from 9 to11 months and 894 kcal/day from 12 to 23 months (Dewey & Brown, 2003). Around 156-237 g per day of the complementary porridges would be required to meet the required energy for infants depending their age. Adding foods containing more lipids to the porridges would be beneficial to increase energy density and provide needed nutrients (Dewey & Brown, 2003). As indicted the figure 11, the curve indicted that the energy contents of SBP samples decreases as the peanut ratio decreases.

4.3. Mineral contents of SBP flour

Table 8 displays the mineral composition of all samples and components of SBP samples. At the 1% probability level or (P≤0.01), models that were fitted for the contents of all minerals showed that the lack-of-fit p-values were not significantly different. A normality plot of the residuals, one of the diagnostic techniques, showed that the residuals of all the response variables are normally distributed.

Table 6. Mineral content of SBP flour samples

Std	Run	Block	SBP		Mineral contents				
			A:	B:					
			Sorghum (g)	Peanut (g)	Calcium Mg/100g	Iron Mg/100g	Zinc Mg/100g	Potassium Mg/100g	Magnesium Mg/100g
7	1	Block 1	70	30	59.90	10.07	5.17	585.49	167.10
3	2	Block 1	85	15	23.84	4.16	3.42	441.56	130.43
6	3	Block 1	100	0	5.07	1.99	2.85	320.16	105.87
2	4	Block 1	70	30	58.95	10.95s	5.41	549.95	166.60
5	5	Block 1	77.5	22.5	38.68	7.65	3.91	492.34	148.73
1	6	Block 1	100	0	5.06	1.98	2.72	324.86	103.90
4	7	Block 1	92.5	7.5	10.61	2.54	3.00	397.96	122.07

SBP= Sorghum Blended peanut, A= Sorghum, B= Peanut,

4.3.1. Calcium content

As shown in appendix table 12, it shows that the linear model of the sorghum blended with peanut flour had a strong linear significance (P≤0.01) and a significant strong interaction effect (P≤0.01) on the calcium content. The calcium content of 70 gram of raw sorghum and 30 gram of peanut was 59.90 mg/100g while the lowest calcium content of 100:0 ratio raw sorghum and peanut was 5.07 mg/100g respectively (Table 6). As seen from the table 8, the results indicated that the control

group of the study has the lowest calcium contents and sorghum is not commonly not a good source of calcium as seen from different literatures. According to the finding of the study, the results was shown that calcium concentration increased sharply as increased the peanut ratios, about the ratio of 70:30 gram of sorghum and peanut gives 59.90 mg/100g of calcium and the ratio of 77.5:22.5 of gram sorghum and peanut gives 38.68 mg/100g respectively, this result is inline the RDA for the infants. The RDA for 6 to 12 months was 270 mg per day (Trumbo, Schlicker, Yates, & Poos, 2002). The current blended product was meet the RDA for life stage of infant, which is 22.18% for the highest blend formulation ratio. The regression model for calcium content was shown by (Eq.27) as indicated in quadratic model with two variables

$$Y = 4.89_{x_1} + 59.44_{x_2} - 36.92_{x_1x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\text{eq. }27$$

Where Y= Calcium content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

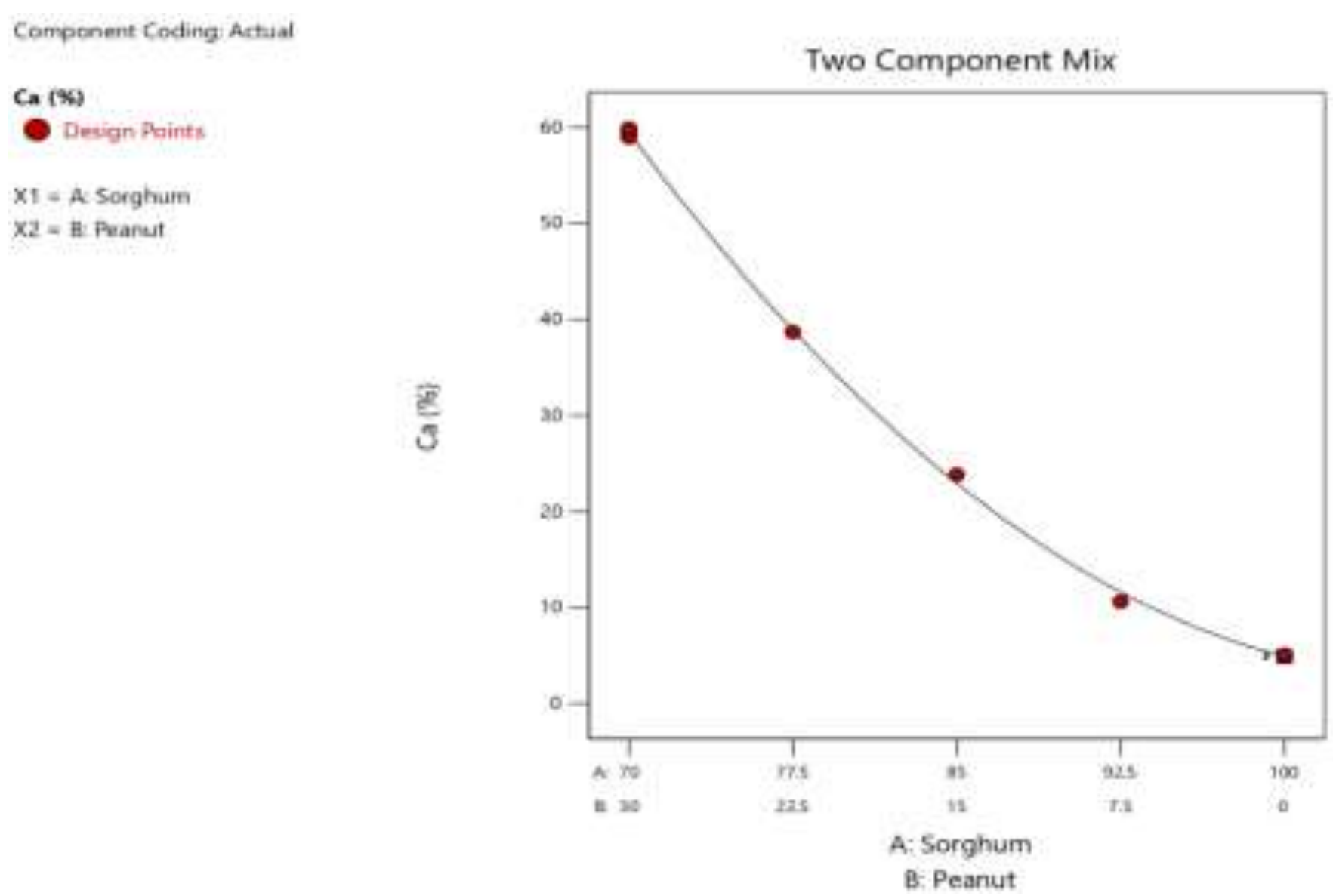


Figure 12. Contour line showing the calcium content while the black points show the treatment formulations of the SBP flour.

4.3.2. **Iron content**

As seen in appendix table12, it indicated that the linear model of the sorghum blended with peanut flour had a strong linear significance (P≤0.01), and a significant strong interaction effect (P≤0.05) on the iron content. The iron content of all the formulations ranged from 1.98 mg/100g to 10.95 mg/100g (Table 6). The amounts of iron of the product were within recommended level

(9mg/1000kcal) for local diets formulated for malnourished children (Golden, 2009). Due to the higher amount of peanut flour, the iron content of the sorghum that has been enhanced with peanuts increased. According to the finding of the study results were within recommendations and there is a reasonable result which agrees with RDA of infants and children.

Also, this result is in line with other studies, the level of iron in sorghum based complementary food observed in this study were comparable (5.56-6.21 mg/100 g) with those reported by (Mosha, Laswai, & Tetens, 2000). The iron content of the current study was ranged from 3.89 to 21.95 mg/100g whereas the RDA for 6-to-12-month life stage infant is 11 mg/ day and 7 mg/day for 13 to 36 months life stage children respectively. The blended product was meet 18.09 to 99.54 % of the RDA for 6-to-12-month life stage infants and 28.28 to 100% for 13 to 36 months life stage children in lower and higher value respectively. The regression model for iron content was shown by (Eq.28) as indicated in quadratic model with two variables.

$$Y = 1.92_{x_1} + 10.63_{x_2} - 7.63_{x_1 x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \text{eq. } 28$$

Where Y= Iron content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

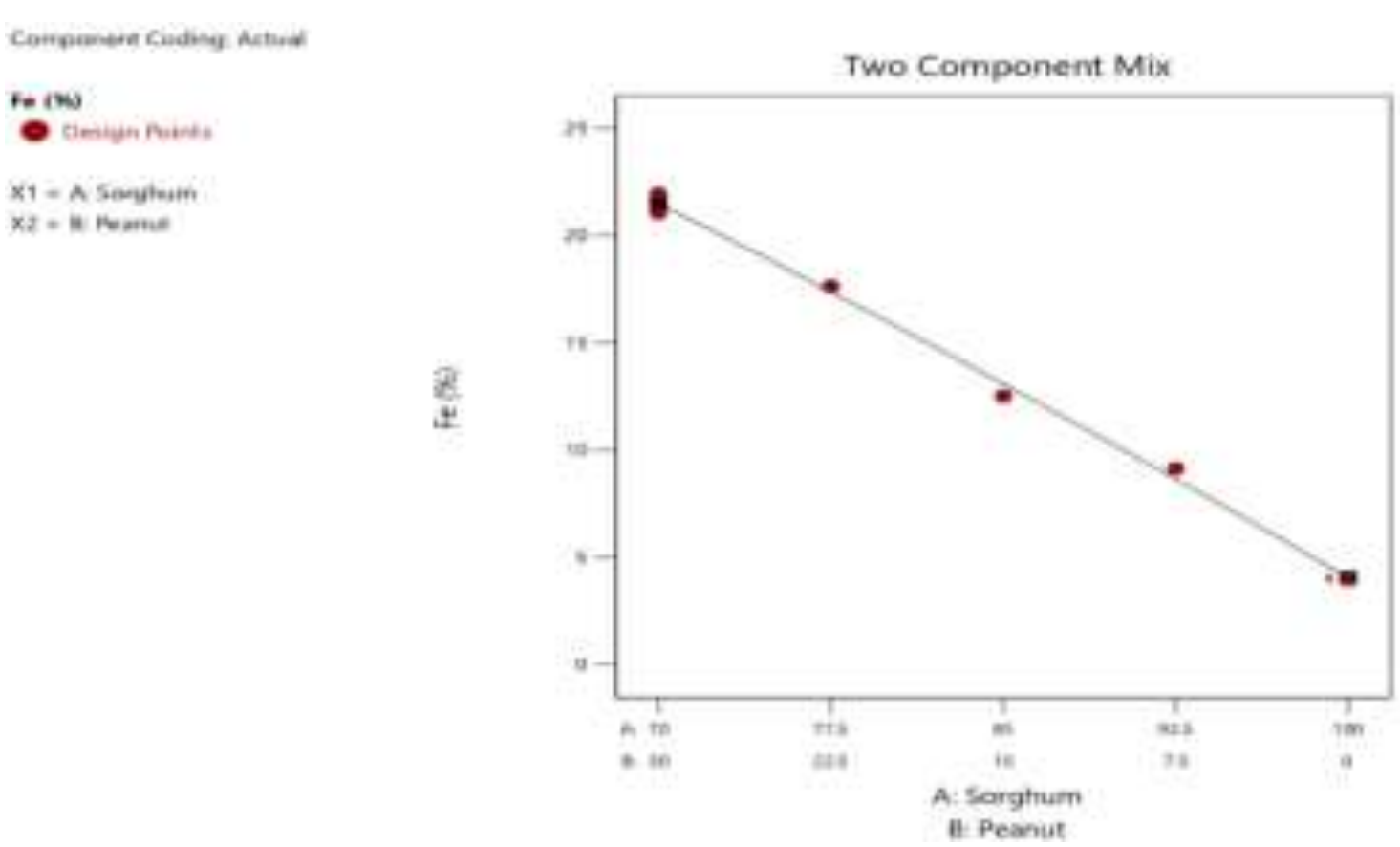


Figure 13. Contour line showing the iron content while the black points show the treatment formulations of the SBP flour

4.3.3. Zinc content

As seen in appendix table12, it indicated that the linear model of the sorghum blended with peanut flour had a strong linear significance (P≤0.01), and a significant strong interaction effect (P≤0.05) on the iron content. Zinc content of sorghum, and peanut flour samples were represented in table 8. The zinc content of SBP samples flour were ranged from 2.72 to 5.17 mg/100g, this finding

agrees with similar reports by (Rasmata, Fatoumata, Wend-Bénédo, Pengdwendé, & Aly, 2023), the study indicated that nutritional and organoleptic characteristics of six formulated sorghum based complementary foods, the zinc content was ranged between 2.01 to 3.7 mg/100g.

According to the finding of this study, it agrees to RDA of the infants and children. The RDA for both 6-to-12-month, 13 to 36 months life stage infant and children are 3 mg/ day. The blended product was meet 90.67 to 100 % of the RDA for both 6-to-12-month and 13 to 36 months life stage infants and children in lower and higher value respectively. According to the existing literatures zinc is one of the most essential minerals for infants and it helps to the brain growth. As indicated in figure 14, the zinc content was decreased as the peanut ratio decreases. The regression model for iron content was shown by (Eq.29) as indicated in quadratic model with two variables.

$$Y = 2.82_{x_1} + 5.24_{x_2} - 2.79_{x_1 x_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{eq. } 29$$

Where Y= Zinc content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

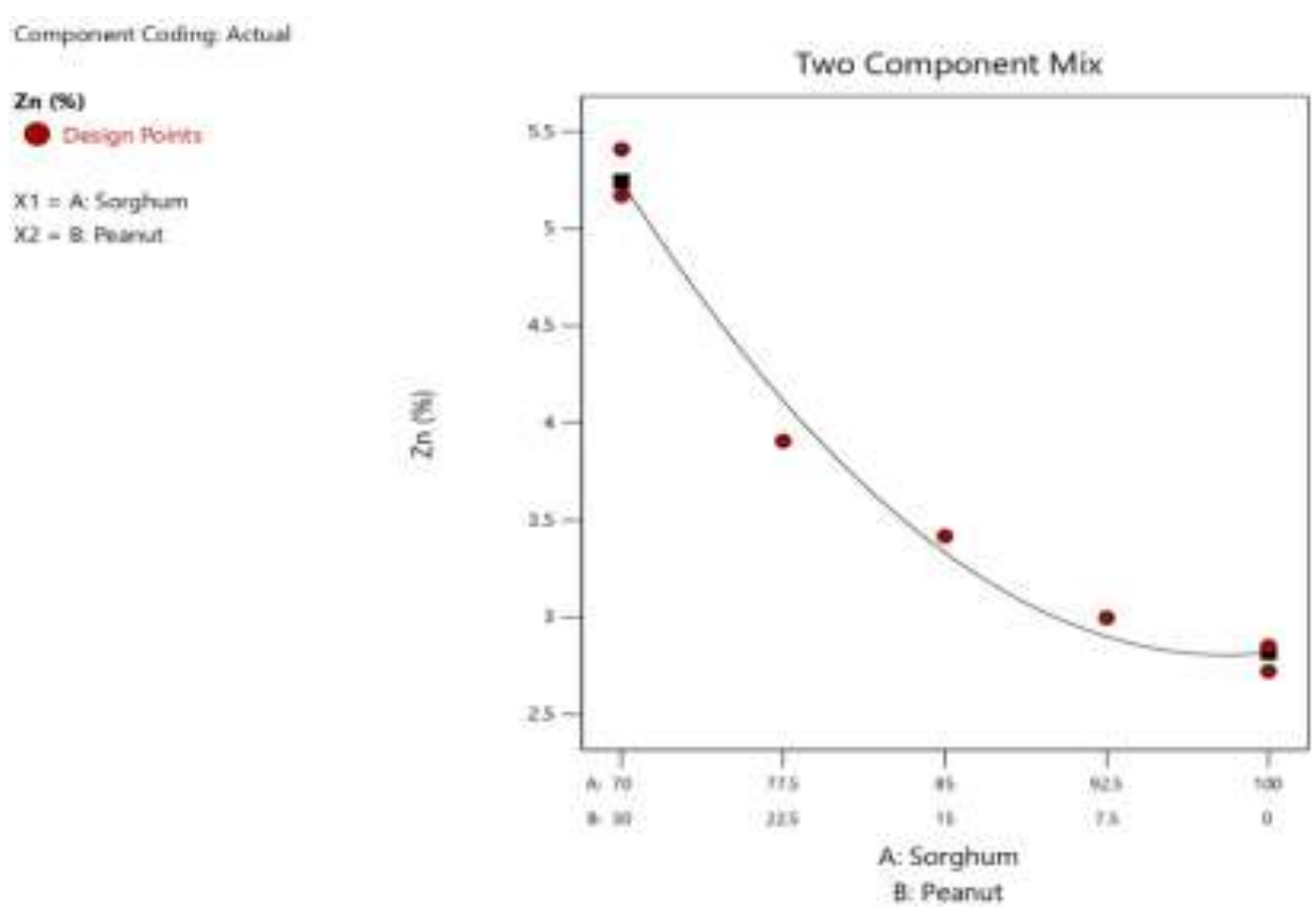


Figure 14. Contour line showing the zinc content while the black points show the treatment formulations of the SBP flour

4.3.1. Potassium content

As seen in appendix table 12, it indicated that the linear model of the sorghum blended with peanut flour had a strong linear significance (P≤0.01). According to the finding of the study, the SBP sample flours have high potassium concentration, as indicated in table 8, the potassium content of SBP samples flour were ranged from 324.86 to 585.49 mg/100g. This finding is a promising result and meets the recommendation of the RDA and the RDA of infants were met in this study but the

children's requirements were not met and this may require further study on the blending ratio of the peanut amounts. The levels of potassium in both products were within the value (1400mg/100kcal) recommended by (Golden, 2009) for moderately malnourished children. Depletion of potassium takes place in all malnourished children.

Supplementary diets should contain sufficient potassium to maintain a renal excretion of 27mg/kg/day and a fecal excretion of 39mg/kg/day (Golden, 2009). The results this study agrees with the RDA of the infants and children. The RDA for both 6-to-12-month life stage infant are 860 mg/ day, and 13 to 36 months life stage infant and children are 2000 mg/ day(Trumbo et al., 2002). The blended product was meet 37.23 to 68.08 % of the RDA for 6-to-12-month life stage infants and 16.01 to 29.27 % of the RDA for 13 to 36 months life stage children in lower and higher value respectively. The regression model for potassium content was shown by (Eq.30) as indicated in quadratic model with two variables.

$$Y = 325.80_{x_1} + 564.74_{x_2} - 7.34_{x_1x_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. eq. 30$$

Where Y= Potassium content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

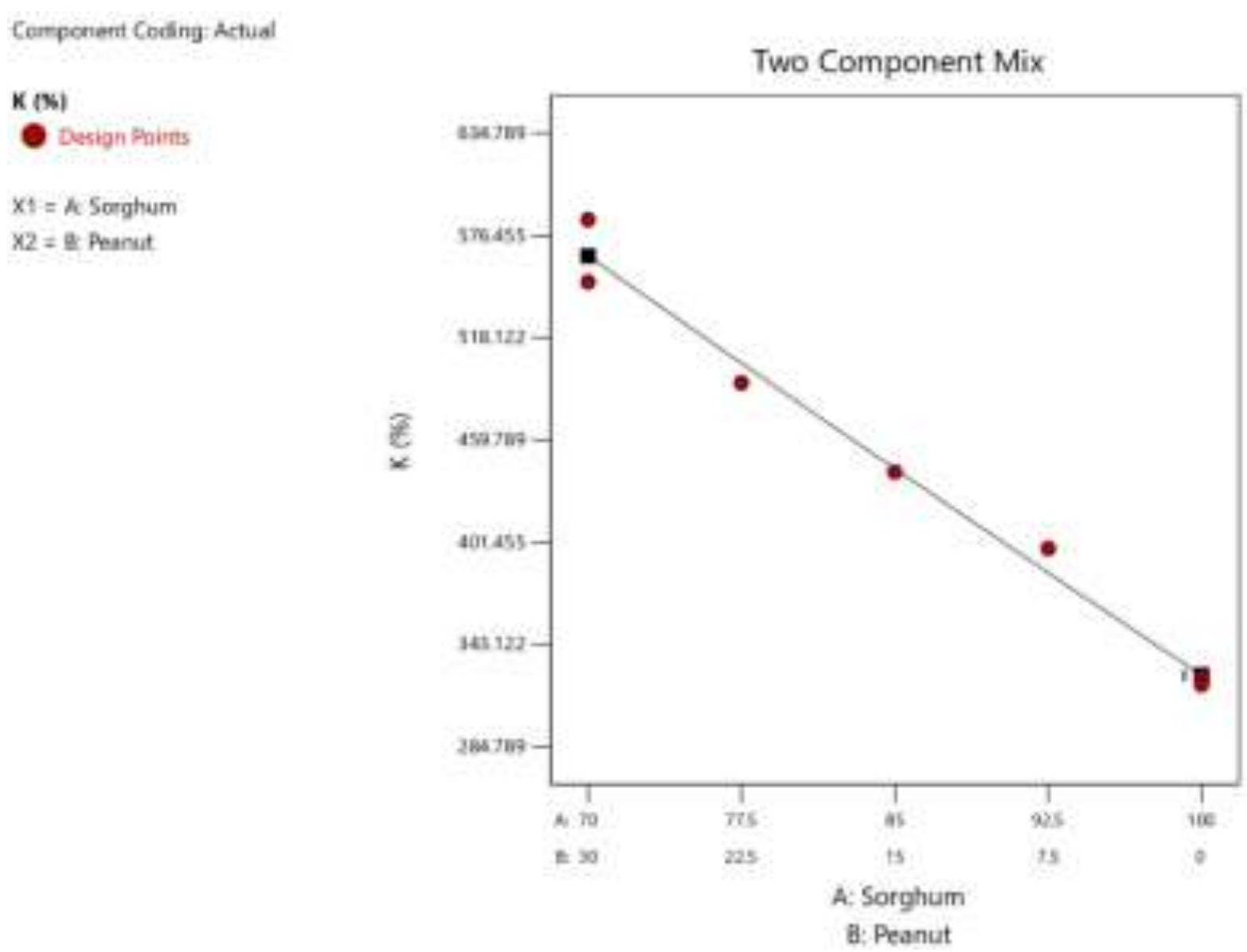


Figure 15. Contour line showing the potassium content while the black points show the treatment formulations of the SBP flour

4.3.2. Magnesium content

As seen in appendix table 12, it indicated that the linear model of the sorghum blended with peanut flour had a strong linear significance (P≤0.01). Magnesium content of sorghum, and peanut flour samples were represented in table 6. The magnesium content of SBP samples flour were ranged from 103.90to 167.10mg/100g. This finding agrees with similar reports by Both products met the recommended levels of 200 mg/1000 kcal (Golden, 2009). Magnesium is a growth nutrient and

deficiency have a negative influence on growth since its deficiency interferes with protein utilization. Magnesium is particularly important for stunted children who need to grow. The regression model for magnesium content was shown by (Eq.31) as indicated in quadratic model with two variables.

$$Y = 105.57_{x_1} + 166.58_{x_2} - 12.53_{x_1x_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. \text{eq. } 31$$

Where Y= Magnesium content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

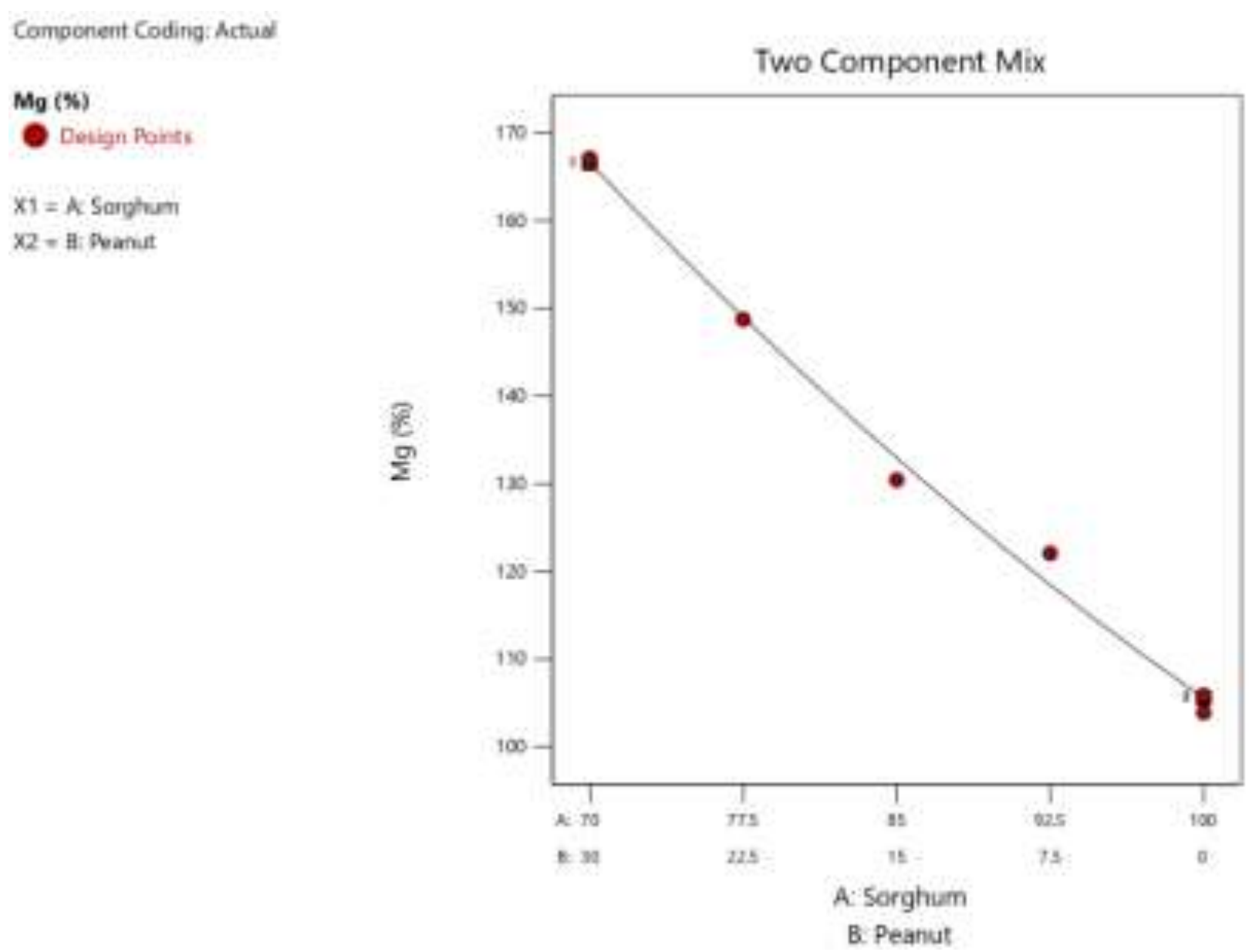


Figure 16. Contour line showing the magnesium content while the black points show the treatment formulations of the SBP flour

4.4. Major anti-nutritional contents

The analysis of the anti-nutritional components (tannin and phytate) in the ingredients and composite flour SBP samples produced the results shown in (Table 6). At the 5% probability level or ($P \leq 0.05$), models for anti-nutritional factors that were fitted showed that the lack-of-fit p-values were not significantly different. A normality plot of the residuals, one of the diagnostic techniques, showed that the residuals of all the response variables are normally distributed.

Table 7. Proximate composition of porridge and ingredients flour samples

Std	Run	Block	SBP		Anti-nutritional	
			A:	B:		
			Sorghum (g)	Peanut (g)	Phytate (%)	Tannin (%)
7	1	Block 1	70	30	98.84	0.20
2	2	Block 1	85	15	122.45	0.31
6	3	Block 1	100	0	143.95	0.45
3	4	Block 1	70	30	99.79	0.21
5	5	Block 1	77.5	22.5	117.03	0.30
1	6	Block 1	100	0	146.97	0.45
4	7	Block 1	92.5	7.5	129.70	0.33

SBP= Sorghum Blended peanut, A= Sorghum, B= Peanut

4.4.1. Phytate contents

As indicated in appendix table 13, it indicated that the linear model of the sorghum blended with peanut flour had a strong linear significance ($P \leq 0.01$). According to the finding of the phytates of SBP sample flour were ranged between 98.84 to 146.03%, these results indicated that the anti-nutritional factors of the SBP sample flour increased as the peanut ration decreases and indicates that the sorghum has higher anti-nutritional factors compared the peanut ration on other hand its good ideas increasing the peanut ratio to minimize the phytates. The effect of blending ratio on phytate content was shown in mixture contour graph (Figure 17) and the regression model was shown by (Eq. 32) as indicating in quadratic model with two variables.

$$Y = 144.36_{x_1} + 100.52_{x_2} + 2.61_{x_1x_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{eq. } 32$$

Where Y= Phytate content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

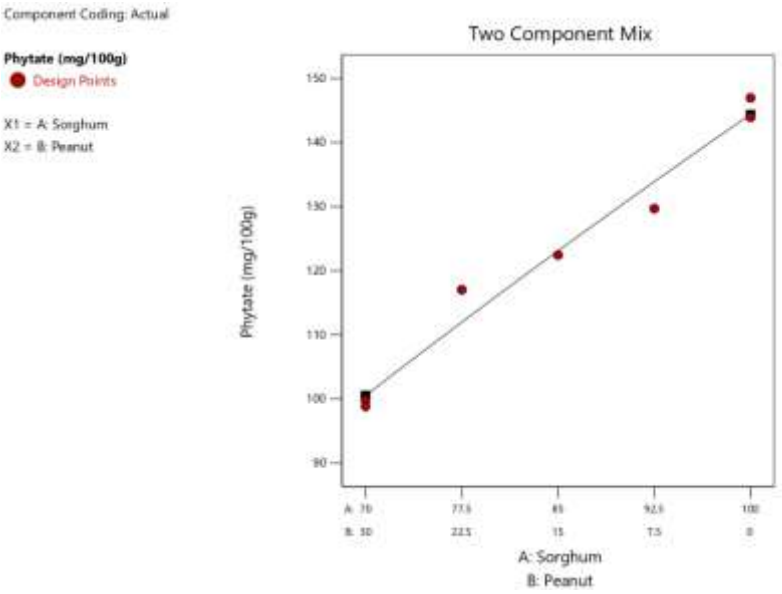


Figure 17. Contour line showing the phytate content while the black points show the treatment formulations of the SBP flour

This study also agrees with research conducted by (Alemayehu, 2014), the result indicated that the phytate content increased from 95.94 to 115.13mg/100g as sorghum flour proportion increased in the composite flour from (40-55%). As shown in curve line on the figure 17, the results indicated that effect of the blending ratio of the phytates from the sorghum and lowest phytate was observed on the blending ratio of 70:30 gram of sorghum and peanut respectively.

4.4.2. Tannin contents

As indicated in appendix table 13, the tannin content indicated that the linear model of the sorghum blended with peanut flour had a strong linear significance (P≤0.01). The results showed that the tannin factors of the SBP sample flour increased as the peanut ration decreased and that the sorghum has higher tannin factors compared to the peanut ration; however, it is wise to increase the peanut ratio in order to reduce the phytates. The tannin of the SBP sample flour ranged from 0.20 to 0.45%. The difference in tannin content may be explained by the increased tannin content of sorghum in comparison to peanuts. Also study in in line with reports of, Local red sorghum has a greater tannin concentration than Meko sorghum (1.29 mg/100g; 3946.94 mg/100g). The tannin level of Meko sorghum flour was found to be 1.29 mg/100g, while (Shimelis & Rakshit, 2005) claimed that the tannin content in meko variety of sorghum flour was below detection limit in his study on improvement of energy and nutrients density of sorghum based complementary meal. The regression model for tannin content was shown by (Eq.33) as indicated in quadratic model with two variables.

$$Y = 0.44_{x_1} + 0.22_{x_2} - 0.07_{x_1x_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{eq. } 33$$

Where Y= Tannin content, X_1= Sorghum, X_2=Peanut, X_1X_2=Sorghum and Peanut

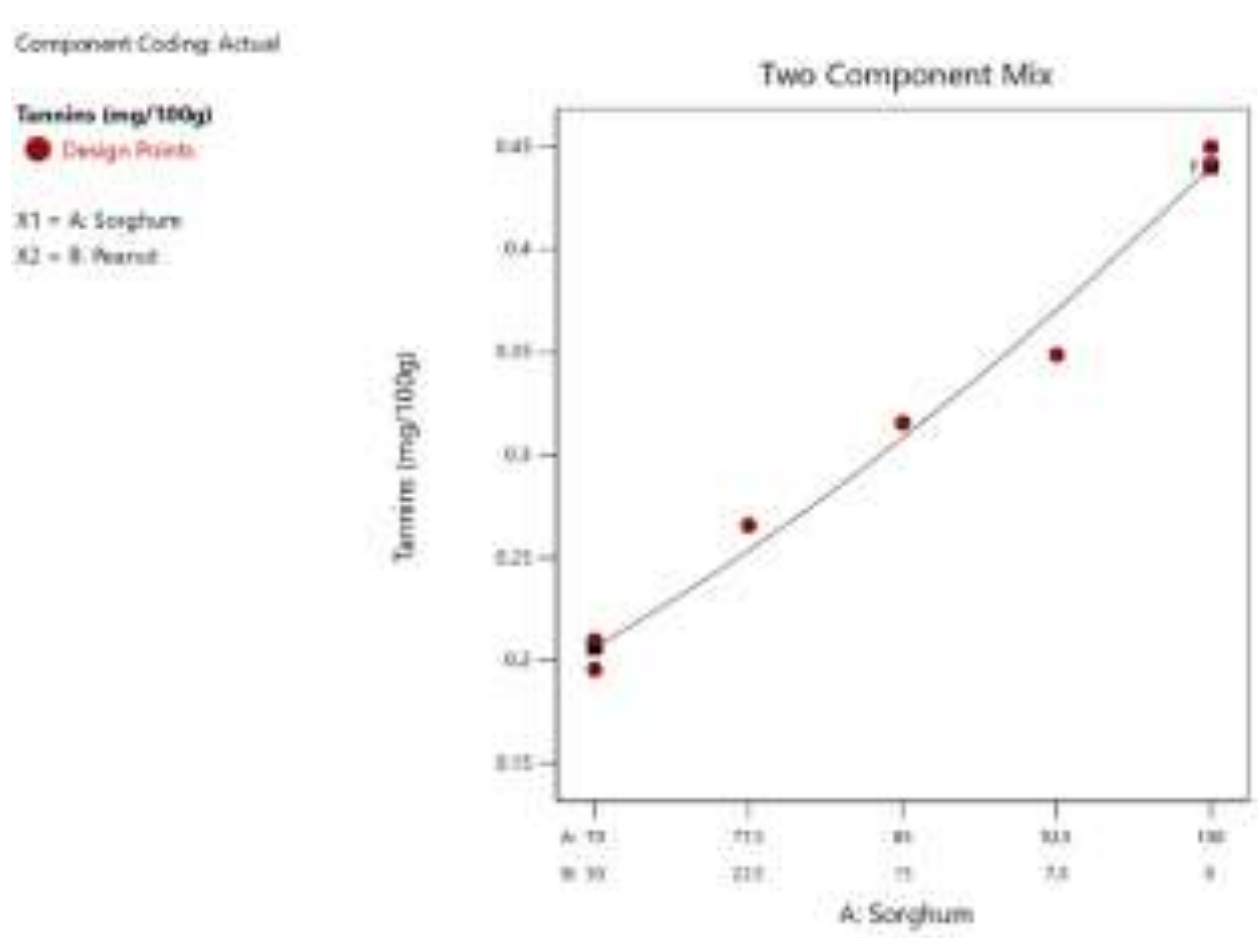


Figure 18. Contour line showing the tannin content while the black points show the treatment formulations of the SBP flour

4.5. To evaluate the sensory properties of SBP product by untrained panels

The sensory evaluation's findings were displayed in (Table 8). According to the average sensory assessments of the SBP product's color, scent, taste, mouth feel, and overall acceptability, the inclusion of peanut flours significantly changed the product's sensory attributes.

With numerical values ranging from 3.40 to 4.71, 3.40 to 4.70, 4.15 to 4.84, 4.34 to 4.87, and 4.50 to 4.483, respectively, the mean scores showed acceptability (degree of like) of porridge for color, scent, flavor, mouth feel, and overall acceptability. It is hard to create a product with all five sensory characteristics that would please customers in most situations, hence the ideal formation should enhance consumer approval (Moskowitz, 1994).

Table 8. Sensory mean scores for SBP sample evaluated by untrained panels

Std	Run	Block	SBP		Sensory Properties				
			A:	B:					
			Sorghum (g)	Peanut (g)	Color	Aroma	Taste	MF	OA
7	1	Block 1	70	30	4.71^{a}	4.70^{a}	4.84^{b}	4.80^{b}	4.83^{b}
2	2	Block 1	85	15	4.27^{d}	4.27^{d}	4.65^{d}	4.69^{d}	4.73^{d}
6	3	Block 1	100	0	3.40^{g}	3.40^{g}	4.15^{g}	4.43^{f}	4.50^{g}
3	4	Block 1	70	30	4.63^{b}	4.63^{b}	4.88^{a}	4.87^{a}	4.86^{a}
5	5	Block 1	77.5	22.5	4.47^{c}	4.47^{c}	4.71^{c}	4.72^{c}	4.75^{c}
1	6	Block 1	100	0	3.55^{f}	3.551^{f}	4.16^{f}	4.34^{g}	4.59^{f}
4	7	Block 1	92.5	7.5	4.20^{e}	4.20^{e}	4.57^{e}	4.46^{e}	4.70^{e}

Means with the same superscript letters are not significantly different ($p<0.05$). MF = Mouth feel, OA= Over all acceptability. The values indicated that 1. Dislike Very Much, 2. Dislike, 3. Neither Like or Dislike 4. Like 5. Like Very Much

4.6. To determine the Optimum blending ratio of SBP Product

Optimization was carried out by setting criteria for each response to obtain the optimum levels of the responses in the experiment. The optimization was to get the maximum puffing scale, rollability scale, crude protein, crude fat, crude fiber, total ash, total carbohydrate, total energy, calcium, iron, zinc, and overall acceptability. The goal of the current research was to establish the ideal ratio for blending each ingredient to create porridge with the desired nutritious contents and sensory appeal. The carbohydrate content of the optimized sorghum flour was 74.90 grams and peanut flour was 25.10 grams. The acceptability of the overall optimum value for Moisture, protein, fat, fiber, ash, carbohydrate, energy, Mg, Ca, Fe, K, Zn, BD, WAC, Phytate, tannin, and overall acceptability varied between 16.16%, 13.65%, 6.14%, 3.08%, 3.40%, 57.59%, 417.79

Kcal/100g, 154.91, mg/100g 45.50 mg/100g, 18.85 mg/100g, 525.09 mg/100g, 4.47 mg/100g, 108.04mg/100g, 0.24%, 0.60g, 133.16%, 3.64%, and 4.81 respectively.

Table 9. Response optimization for proximate, physicochemical, and anti-nutritional contents of SBP flour

Name	**Unit**	**Lower Limit**	**Upper Limit**	**The optimum value of the SBP Flour**
A:Soghum	g	70	100	74.90
B:Peanut	g	0	30	25.10
Moisture	%	12.43	17.38	16.16
Protein	%	4.40	15.61	13.65
Fat	%	5.34	6.35	6.14
Fiber	%	1.32	3.98	3.08
Ash	%	1.05	3.61	3.40
Carbohydrate	%	54.08	75.33	57.59
Energy	Kcal/100g	388.86	423.81	417.79
Mg	mg/100g	103.90	167.10	154.91
Ca	mg/100g	5.06	59.90	45.50
Fe	mg/100g	3.99	21.95	18.85
K	mg/100g	320.16	585.49	525.09
Zn	mg/100g	2.72	5.41	4.47
BD	g/ml	98.84	146.97	108.04
WAC	%	0.20	0.45	0.24
WAI	g	0.59	0.68	0.60
Phytate	%	128.15	134.00	133.16
Tannin	%	3.62	3.72	3.64
Overall acceptability	Scale	4.501	4.861	4.81
Desirability	--	--	--	0.68

4.7. Conclusion And Recommendation

4.7.1. Conclusion

One third of the world's population relies heavily on cereals as a source of nourishment, particularly in underdeveloped nations. Sorghum is one of these grains that has a variety of uses that makes it one of the most significant crops and a significant source of calories for human nutrition. The findings of this study showed that adding a maximum of 30% of peanut flour to the composite flour formula greatly enhanced the product's macronutrient profile (protein, fat, carbohydrate, and energy content).

Additionally, the product's level of micronutrients including calcium, iron, zinc, magnesium, and potassium dramatically rose as the quantity of peanut flour increased. As the amount of peanut flour grows to 30%, the concentration of anti-nutritional elements such phytate and tannin in the SBP product falls. According to the findings of the SBP products' overall sensory acceptability test, the color, scent, taste, and mouth feel of the goods considerably changed when the amount of peanut flour was increased. This boosted the products' overall acceptability.

To improve physicochemical attributes, proximate composition, mineral concentrations, and sensory acceptance, the composition of SBP sample flours was numerically optimized. The formulation condition of 74.90% sorghum flour and 25.10% peanut flour was determined to be the best for all the tested parameters.

4.7.2. Recommendation

The following points have been proposed as potential lines of investigation for any researchers based on the study's findings.

- The microbiological analysis and shelf life of the composite flour should be the subject of further research.
- More research on roasted peanuts is needed to enhance the flavor of blended products.
- More study has to be done on how to determine the amino acid profile of composite flour.
- The complementary meals must be advertised.

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APPENDICES

Appendix Table 10. Regression coefficient of a quadratic polynomial, R2, and lack of fit for functional properties of SBP flour

Source	Bulk Density (%)	Water Absorption Capacity (%)	Water Absorption Index (g)
Model	0.93*	36.71**	0.01**
Linear mixture	0.93**	36.65**	0.01**
A	5.39*	128.30	3.62**
B	6.29*	134.01	3.72**
AB	-0.05	0.94	0.02
Adj. R^2	0.97	0.99	0.97
Lack of fit	0.45	0.32	0.64
Std. Dev.	0.07	0.20	0.01
C.V. %	1.25	0.15	0.18
Mean	5.83	131.24	3.67

A= Sorghum, B= Peanut, *Significant at P≤ 0.05 level, **Significant at P≤ 0.01

Appendix Table 11. Regression coefficient of a quadratic polynomial, R2, and lack of fit for proximate composition of SBP flour

Source	MC	C.Protein	C.Fat	C.Fib	C.Ash	Total CHO	Energy Kcal/100g
Model	0.93**	21.67**	126.14**	5.01**	7.82**	387.95**	1670.94**
Linear mixture	0.93**	21.66**	125.67**	4.74**	7.22**	386.99**	1666.46**
A	5.39**	12.50**	4.46**	1.42**	1.34	75.23**	391.09**
B	6.29**	16.89**	15.03**	3.48**	3.87	56.68**	429.58**
AB	-0.05	-0.13	2.48	1.87	-2.79**	-3.54*	7.63
Adj. R^2	0.97	0.97	0.99	0.86	0.9936	0.99	0.98
Lack of fit	0.45	0.95	0.74	0.28	0.49	0.1113	0.80
Std.Dev.	0.07	0.34	0.42	0.35	0.0915	0.57	2.52
C.V. %	1.25	2.28	4.17	13.53	3.89	0.87	0.61
Mean	5.83	14.69	9.97	2.62	2.35	65.64	411.01

A= Sorghum, B= Peanut, MC=Moisture Content, P=Protein, Crude Fib= fiber, CHO=Carbohydrate, *Significant at P≤ 0.05 level, **Significant at P≤ 0.01

Appendix Table 12. Regression coefficients of a quadratic polynomial or linear model, R2, and lack of fit for the selective mineral of SBP flour samples

Source	Calcium Mg/100g	Iron Mg/100g	Zinc Mg/100g	Potassium Mg/100g	Magnesium Mg/100g
Model	3452.83**	89.38**	7.24**	64231.38**	4199.20**
Linear mixture	3347.84**	85.24**	6.64**	64227.23**	4187.11**
A	4.89**	1.92**	2.82**	325.80**	105.57**
B	59.44**	10.63**	5.24**	564.74**	166.58**
AB	-36.92**	-7.33*	-2.79*	-7.34	-12.53
Adj. R^2	0.9990	0.98	0.9791	0.9769	0.9920
Lack of fit	0.1924	0.45	0.3594	0.6405	0.0919
Std. Dev.	0.7666	0.47	0.1599	15.84	2.37
C.V. %	2.66	8.34	4.23	3.56	1.75
Mean	28.87	5.62	3.78	444.62	134.96

A= Sorghum, B= Peanut, *Significant at P≤ 0.05 level, **Significant at P≤ 0.01

Appendix Table 13. Regression coefficient of a quadratic polynomial, R^2, and lack of fit for anti-nutritional properties of SBP flour

Source	Phytate contents (%)	Tannin contents (%)
Model	2162.10**	0.0562**
Linear mixture	2161.58**	0.0558**
A	144.36**	0.4364**
B	100.52**	0.2137**
AB	2.61	-0.0713
Adj. R^2	0.9635	0.9052
Lack of fit	0.0928	0.0142
Std. Dev.	3.67	0.0308
C.V. %	2.99	9.66
Mean	122.67	0.3187

A= Sorghum, B= Peanut, *Significant at P≤ 0.05 level, **Significant at P≤ 0.01