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Development of Anchote (*Coccinia Abyssinica*) based Ready to Eat Baby Food Products

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This is to certify that the thesis prepared by Iyob Deresa, entitled: *Development of Anchote (Coccinia Abyssinica) based Ready to Eat Baby Food Products* and submitted in partial fulfilments for the requirements for the degree of masters of science (Chemical and Bio Engineering) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Abstract

Anchote is an endemic and potentially valuable crop of Ethiopia and nutritionally, it is a good source of minerals and fiber. The crop is used as food security plant during food shortage since they are drought-tolerant and high yielding. This study was aimed at developing and enhancing the value of anchote based ready to eat food products for the babies in the age group of 6 to 18 months using drum dryer, and to evaluate their suitability and wholesomeness. Accordingly, anchote, oat and soybean were selected based on their nutritional value, affordability and availability to develop a protein and energy complementary food. Response surface methodology (RSM) was implemented to study the effect of drum drying process parameters on proximate and mineral composition, antinutritional factors, physical and functional properties, microbial load and sensory quality attributes. By applying mixture design D-optimal software, a formulation containing 54.11g/100g anchote, 26.59g/100g oat, and 19.28g/100g soybean flour was selected as the best source of energy (380.03kcal) and protein (18.01g/100g). The drum drying process variables were: drum temperature (145 and 160°C), drum speed (200 and 300 rpm) and product particle size (0.6 and 0.8mm). The optimum protein and energy contents of the product obtained at 145^{o}C drum temperature, 200rpm drum speed and 0.6mm particle size were 18.68% protein, 5.3 % fat, 4.27% ash, and 68.94 % total CHO and 399.82kcal/100g of utilizable energy. The vitamin B2, Ca, Zn, Fe, Mg and K contents of drum dried products were (0.48, 168, 0.51, 1.46, 86 and 54 mg/100g) higher than the raw formulated flour (0.46, 148, 1.24, 0.22, 81.03 and 68mg/100g). The antinutritional reduction of phytate was from 190.34 to 113.41mg/g and that of tannin was from 12.23 to 3.89mg/g. The functional properties: namely water absorption, oil absorption, swelling power, dispersibility and solubility (2.75g/mL, 1.48mL/g, 3.75g/g, 65.77% and 63.2%) of the drum dried products were higher than that of formulated raw flour (1.26ml/g, 1.42mL/g, 2.68g/g, 50.5% and 41.23%) due to starch gelatinization. The sensory results of the product produced at a drum temperature of 160^{o}C, drum speed of 300 rpm and particle size of 0.6mm was perceived as the most acceptable ones. Microbiological analysis results showed that Coliform and E. coli were not detected in all products. The total plate count, yeast and mold count analysis showed results in the safe limit according to FAO and WHO recommendations. The optimum protein and energy contents of the product obtained at 145^{o}C drum temperature, 200rpm drum speed and 0.6mm particle size content have been found to be ideal operating variables for production of anchote-based ready to eat baby food product.

Keywords: *Anchote, D-optimal mixture, Drum dryer, Oat, Ready to eat baby food, Soybean.*

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List of Abbreviations

ANFs	Anti-Nutritional Factors
ANOVA	Analysis Of Variance
AOAC	Association of Official Analytical Chemists
BD	Bulk Density
CSA	Central statistical agency
FAO	Food and Agricultural Organization
OAC	Oil Absorption Capacity
PAG	Protein Advisory Group
PEM	Protein Energy Malnutrition
RPM	Rad per Minute
SWP	Swelling Power
USAID	United States Agency for International Development
WAC	Water Absorption Capacity
WFP	World Food Program
WHO	World Health Organization
RDI	Recommended Daily Intake
CAC	Codex Alimentareous Commission

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CHAPTER ONE

INTRODUCTIONS

1.1 Background

Complementary foods are foods and liquids other than breast milk or infant formulas required during the second part of the first year of life for both nutritional and developmental reasons and also to enable transition from milk feeding to family foods (Koletzko *et al*., 2008). After 6 months of age, breast milk is not enough to meet the macro- and micronutrient requirements of infants (Ijarotimi & Keshinro, 2013; Koletzko *et al.*, 2008). Infants also develop the ability to chew; hence, begin showing interest for foods other than milk, therefore, there is the need to introduce healthy complementary foods. According to the Codex Alimentarius Commission (2008), complementary foods should be of appropriate nutritional quality and energy to complement the nutrients obtained from breast milk for infants and family foods for younger children.

Complementary food play vital role for children growth and development and complements for both Nutritional and developmental needs of the infant when breast milk alone is no longer sufficient. In Ethiopia, a combination of nutritionally inferior diets and improper feeding practices are major contributing factors to the development of childhood malnutrition (Rubery, 1988; Jakobs, 1991). According to WHO (2003), good quality complementary food must have high nutrient density, low viscosity, bulk density and appropriate texture along with high energy, protein & micronutrient content, have low consistency that allows easy consumption (Balasubramanian & Singh, 2014).

Traditional infant foods made of cereals or grains are bulky and may be low in several nutrients including protein, vitamin A, zinc iron and contain high amount of anti-nutritional factors reducing mineral bioavailability, such as phytates and tannin which is the potential for stunting in children (Melaku *et al*, 2005). There is urgent need for provision of complementary foods rich in protein, low cost and suitable for provision of infants' nutritional needs. Unfortunately, this is lacking especially in rural parts of developing countries (Abbey *et al.,* 1988). There is urgent need for provision of baby foods rich in protein, low cost and suitable for provision of infants' nutritional needs. Unfortunately, this is lacking especially in rural parts of developing countries (Abbey *et al.,* 1988).

In Ethiopia, root and tuber crops have a great contribution as part of the traditional food system and income generation specifically in Southern, South Western and Western part of the country (Andargachew *et al.*, 2011; Fantaw *et al*., 2014). From these crops one of the well-known is Anchote (*Coccinia abyssinica*) which is belongs to Cucurbitaceae family which is one of the most economically important families of plants (Schaefer *et al*., 2009). These crops are mainly used as food security plants during food shortage since they are drought-tolerant and high yielding (Wheatly *et al*., 1995). Anchote is an endemic and potentially valuable crop of Ethiopia principally categorized under root and tuber crops (Amare, 1973).

Nutritionally, anchote is a good source of minerals and fiber content. Its protein content is also by far greater than other root crops, although, root crops are known for their low protein content. It is rich source of calcium, which is an important constituent of our bones and teeth. Anchote is also an ample source of potassium and iron. So it can contribute to the food security in the country (Habtamu, 2011). In jovial occasion and holydays tubers of Anchote are cooked in sliced form and pounded after mixing with plenty of butter made from cow milk and spices (Amare, 1973). Nutritionally, the crop has appreciable nutritional composition mainly of protein and calcium (Desta, 2011; Habtamu *et al.*, 2013; Habtamu & Kelbessa, 1997).

The tuber is prepared in different ways for consumption. In one way, it can be cooked simply and served with a traditional fermented spice 'Kochkocha' prepared from coriander (Coriandrum sativum), sweet basil (Ocimum basilium), ginger (Zingiber officinale), garlic (Allium sativum) and salt. It is also used to prepare a soup after drying and grinding in to powder (Habtamu & Kelbessa, 1997). In jovial occasion and holydays tubers of Anchote are cooked in sliced form and pounded after mixing with plenty of butter made from cow milk and spices (Amare, 1973). Nutritionally, the crop has appreciable nutritional composition mainly of protein and calcium (Desta, 2011; Habtamu *et al*., 2013; Habtamu & Kelbessa, 1997).

Soy protein has been known as an abundant and cost competitive source of protein ever since it was noticed in the 1930s. The advances in soybean production and soy protein processing technology give soy protein a broader and more versatile utilization in human foods (Liu, 1997). Khalil (2006) described that in developing countries, there is an urgent need of nutritious foods to meet the nutritional requirements of ever increasing populations. Therefore, products from soybean are exceedingly required for those populations in Ethiopia affected by protein-energy malnutrition and for those who have constraints to inclusion of animal source foods in their diets.

Oats are one of the most nutritious grain cereals, high in protein and fiber. Oat protein is generally greater than that found in other cereal grains. It contains high amount of vitamins and minerals (Ahmad and Zaffar, 2014). Oats are an important source of nutrients; they contain protein, di-gestible carbohydrates and dietary fiber fractions required for a balanced human diet. Oats can be used as oat meal, oat flour, oat bran and oat flakes as breakfast cereals and as ingredients in other food stuffs. Oat cereal is one of the cheapest sources of carbohydrate, fiber and beta glucan. According to FAO, the average oat grain production in Ethiopia holds (50,000 t/year from 49,000 ha).

The drum dyer is an old food processing equipment that was developed in the early 1900s. Its main purpose was for drying most liquid food materials until the invention of the spray dryer. It could dry slurries, liquid or dough materials into thin sheets which could then be made into flakes or powders (Tang, J., Feng, H. and Shen, 2003.). Specifically, the drum dryer could be used to dry thick liquids, pulps, pastes or slurries, mashed potatoes, carrots, soups, baby cereals, etc. (Bonazzi C. and Dumoulin E, 2011). It has also been used to dry sweet whey, which is used as a sugar replacer in French-type bread and butter cookies with good sensorial and nutrient attributes (Mustafa *et al.,* 2014).

1.2 Statement of Problems

Optimal infant and young child feeding practices rank among the most effective interventions to improve child health. In 2006 an estimated 9.5 million children died before their fifth birthday, and two thirds of these deaths occurred in the first year of life. Under-nutrition is associated with at least 35% of child deaths in Sub-Saharan Country. It is also a major disabler preventing children who survive from reaching their full developmental potential (WHO, 2009). Consequently, malnutrition in Ethiopia continues to increase, affecting primarily women and children (Melese, 2013). The prevalence rates of stunted growth and wasting, vitamin A, iodine, iron and zinc deficiencies derived from national and localised surveys shows the magnitude of malnutrition in Ethiopia (Kaluski *et al.*, 2002).

Child malnutrition is a major global health problem, leading to morbidity and mortality, impaired intellectual development and working capacity, and increased risk of adult disease (Kim et al., 2009). 10 million children under the age of 5 years old die each year (Bryce *et al.,* 2005). More than half of the deaths occur because of malnutrition. If adequate health systems were in place nearly 2/3 of the deaths could be prevented. Part of the health systems picture is to promote appropriate feeding practices for infants and young children.

Several studies have reported that most of the complementary foods consumed by the infants in many parts of world are deficient in essential macronutrients and micronutrients leading to malnutrition, which is one of the serious problems in developing countries. According to UNICEF, in Ethiopia every year one million children below the age of five years die due to protein energy malnutrition. Malnutrition and growth retardation have long life consequences for people and their societies, in terms of higher health care costs, lower productivity, and increased poverty.

In Ethiopia, protein-energy malnutrition (PEM) is one of the well-known malnutrition that create serious problems and retards children growth in the country. The high prevalence of malnutrition and persistent food insecurity in Ethiopia is due to the highly selective and restricted food consumption habit of the population as well as less exposure to the important wild and indigenous food plants (Getachew, 2001).

In Ethiopia most infants and young child did not get additional and supportive enriched and balanced food with protein, macro and micro mineral, vitamins, antioxidants and other fortified foods after six months in additions to breast feeding. So, due to this reason most of the young child in the rural area of our country do not grow physically and mentally with their age properly. The big challenges in Ethiopia to access infant and baby food product (complementary food) is due to its high price because most of the products are imported , the shortage of product and there is no enough baby food processing industries from local raw materials.

Anchote has appreciable nutritional composition mainly of protein and high mineral contents like calcium, iron, potassium and due to lack of awareness about the crop itself, there is need to carry out descriptive studies on the crop to elucidate its traits as food crop. Anchote did not get adequate attention in terms of improving its productivity and food utilization value, and hence it has remained as one of underutilized crops of Ethiopia. Imported or commercially developed foods generally are not used by low-income rural households due to high cost and poor availability. Therefore, to improve the nutritional contents of baby food, Anchote should be supplemented with Oats and soybean. Complementary foods should contain animal source foods with high biological value to foster growth and development. However, these foods may not be available to most low-income households in developing countries.

1.3 Objectives

The main objective of this study was to develop and evaluate Anchote (*Coccinia Abyssinica*) based ready to eat baby food (complementary food).

Specific Objectives were to**:**

- ➢ Optimizing mixing ratio of the component (anchote, oat and soybean)
- ➢ Assessments of the nutritional composition and anti-nutritional factors of raw materials, formulated flour and drum dried ready to eat baby food Product
- ➢ Analyze the mineral nutrients and vitamin B2 (Riboflavin) in formulated raw flour and in developed ready to eat baby food products
- ➢ Evaluate the functional properties (water and oil absorption capacity, dispersiblity, swelling power and solubility index) of raw materials, formulated flours and drum dried food product
- ➢ Determine the physicochemical properties (, bulk density, water activity, PH value and viscosity) of formulated flour and drum dried anchote based ready to eat baby food product
- ➢ Evaluate of the effect of drying parameters of the drum dryer on physicochemical, functional and sensory properties of the ready to eat baby food Product
- ➢ Conduct microbiological analysis

1.4 Research Questions

- ❖ Does the variation in the amount of Anchote, Oat and Soybean affect the nutritional, functional, Physico-chemical, sensory and functional properties of drum dried complementary foods prepared from blend of anchote, oat, and soybean?
- ❖ Does drum dry process of Anchote, Oat and Soybean blend flour affect the nutritional, functional, Physico-chemical, sensory and functional properties of ready to eat baby food prepared from blend of anchote, oat and soybean?
- ❖ Does the variation in the drum dry process parameters affect the nutritional, functional, Physico-chemical, sensory and functional properties of drum dried complementary foods prepared from blend of anchote, oat, and soybean?

1.5 Significance of the Study

In Ethiopia, root and tuber crops have a great contribution as part of the traditional food system and income generation. But most of this agricultural products are highly loosed and under utilizations due to lack of different processing technologies and poor post-harvest management system. The bases of this study is focused on the development of anchote-based ready to eat baby food and it also helps to introduce new kind of cost efficient complementary food products. This contributes positive effect in terms of utilization of anchote for developing complementary food which is rich in protein and energy and also used to develop the eating routine of the population. The production of complimentary food through value addition on these locally available anchote tuber will have a great contribution to the country economy not only by utilizing the largely available agricultural resources but also by substituting the import of infant food. Furthermore, utilization of locally available agricultural resources can enhance income generation and provide employment opportunity in the country.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of Anchote, Soybean and Oat Production in the World and Ethiopia

Anchote was originated and endemic to Ethiopia, where it is found as cultivated and in wild form (Amare Getahun, 1973; Edwards *et al*., 1995). The crop is cultivated in backyard, for its rootstock, particularly in southwestern part of Ethiopia, namely Wollega, IlluAbaBora, and Jimma Zones. Other parts, such as Shoa and Harerghe Zones of the Oromia Regional State have also started cultivation of anchote recently (Tesfaye and Abebe, 1988; Karin, 2002). Recent work by Bula Sirika, (2016) shows that anchote crop is also being cultivated in other countries by Oromo Diasporas, including in various states of Canada and United States of America.

However, an early research done on anchote's habitat, by Westphal (1974), indicated that commonly two agro–ecological zones have special connection with it. These regions are: 1) the southeastern part of the Ethiopian highlands, the area situated at altitudes of 1800 m a.s.l. and higher which have Alfisols as a major soil type. This area receives 950–1500 mm average annual rainfall; and 2) South western part of the Ethiopian highlands, which covers areas such as Wollega, Illu Aba Bora and Jimma. Anchote is usually cultivated in rainy season (April to January) which depending on agro ecological zones takes four to five months to mature to consumable or marketable root size, which makes anchote a short season crop.

The yield of anchote varies in different soil types and agro-ecological zones. For instance, one annual report of 2004/5 production season shows that anchote crop was produced nearly on 3,000 hectare of land in West Wollega Zone which yielded a total of 25,000 tons of tuber (Anonymous, 2011). However, maximum tuber yield (76.45 t/ha) was obtained in Ebantu agro ecological condition (Daba Mengash *et al.,* 2012) under experimental condition and even more (80 t/ha) yield was obtained on vertisol soil type at Debre-Ziet Agricultural Research Center (Desta Fekadu, 2010).

The soybean (*Glycine max*) is originated in Eastern Asia, probably in north and central China. It is believed that cultivated varieties were introduced into Korea and later into Japan some 2000 years ago. Soybean entered to Ethiopia 50 years ago. Till now there have been a number of studies conducted on different soybean varieties.

Soybeans have been grown as a food crop for thousands of years in China and other countries of East and South East Asia and constitute to this day, an important component of the traditional popular diet in these regions. Through the studies it has been determined suitable conditions and places for the growth of the soy bean, suitable plantation periods and methods of production, and productive varieties are well known **(**Fouzia, 2009) Soybean is an annual crop, fairly easy to grow, that produces more protein and oil. It is a versatile food plant that used in its various forms, is capable of supplying most nutrients.

Soybean protein quality has been the subject of intense investigation for several decades due to soybean's increasing importance as human food resource (Assefa, 2008). Ethiopian soybean production increased from 1.6 to 28.3 thousand tons in ten years (2003-2012) (CSA, 2012). Major consumers of soybean in the country include Faffa food Share Company, East African flour factory, and Health care food manufacturing private limited company for the preparation of enriched food products and Alema Koudijs for producing animal foods.

Oat (Avena sativa) is only known in cultivation and its exact origin is unclear. Oat was not cultivated as early as wheat and barley and probably it persisted as a weed in fields of these cereals for centuries before it was taken into cultivation. Oat seeds have been found in 4000-year-old remains in Egypt, but these were probably from weeds and not from cultivated oat. (Assefa *et al.,* 2003; Iran1994). Nowadays oat is extensively cultivated in northern temperate regions, mainly in Europe and North America. In Ethiopia, cereals, among which teff, barley, maize, sorghum, oats, millet and wheat, make up 85% and 90% of the total cultivated area and total production of field crops respectively and accounts for over 90% of modern input consumption (CSA, 2000;MEDaC,1999). In tropical Africa it is mainly grown in Ethiopia and Kenya. It is also cultivated in South Africa, Morocco, Algeria and Tunisia.

In Ethiopia oat is made into 'injera', 'tella' and other products. According to FAO statistics the average world oat grain production in 1999–2003 amounted to about 25.9 million t/year from 12.7 million ha. The main producing countries are the Russian Federation (5.8 million t/year in 1999–2003, from 3.8 million ha), Canada (3.3 million t/year from 1.4 million ha) and the United States (2.0 million t/year from 0.9 million ha). The average oat grain production in sub- Sahara Africa in 1998–2003 has been estimated at 55,000 t/year from 53,000 ha,almost entirely from Ethiopia (50,000 t/year from 49,000 ha) and Kenya (3500 t/year from 3400 ha) and small amounts from Zimbabwe. (Feyissa, 2004). The Russian, Canada, United States of America, Finland, and Poland were ranked as the top five countries.

2.2 Nutritional Composition and the Importance of Anchote

Anchote is endemic root crop of Ethiopia and it is a unique root crop in its uses and the parts consumed. All the three harvestable parts of anchote (i.e. seeds, shoot tips and tubers) are marketable even though the root is the most economic concern in most growing areas of Ethiopia. The crop has been contributing much to the diet of the rural societies in its growing areas since its domestication (Amare Getahun, 1976). As its protein, calcium, iron and carbohydrate contents are better than other root crops, it could be an excellent source of macro- and micronutrients. Traditional indigenous crops have the potential to diversify and expand the diet of the local societies in particular, and the world, in general (Habtamu Fekadu, 2011).

In addition to its nutritional importance, anchote is a cultural and medicinal crop widely used in growing areas (Amare Getahun, 1976). Anchote is a local dish highly recommended for individuals suffering from bone fractures and displaced joints. The belief that anchote has a repairing effect is knowledge gained by the Oromo elders from years of practical experience. More than its other uses, anchote is getting popular because of its medicinal value even with the non-Oromos (Abera Hora, 1995). The high medicinal value of the anchote tuber seems to be because of its high calcium as compared to other common and widespread root and tuber crops (Abera Hora, 1995).

Possibly its calcium content is important in repairing damaged bones. Juice prepared from roots of anchote has been used in Ethiopian traditional medicine. Spiced and flavored anchote paste is recommended for people suffering from bone fracture and displaced joints (Amare Getahun, 1976; Habtamu Fufa and Kelbesa Urga, 1997; Endashaw Bekele, 2007). According to Abera (1995), juice of anchote root is used to treat cancer, tuberculosis, skin eruptions and gonorrhea by traditional medicine practitioners of Ethiopia.

According to Abera Hora (1995), Anchote dishes in different forms are usually served in special occasions such as the '*masqal*' celebration in September, weddings, marriage ties (betrothals), circumcision, birth days and thanks giving days at the start of a New Year, or harvest time. During such occasions and/or at times of physical injuries, a neighbor that has no anchote for that season may get a present of anchote tubers from those who have it. This is done to share their happiness and strengthen social relationships. So, anchote has considerable social importance in the anchote growing societies.

Table 2.1: Nutritional and ant nutritional composition of raw and processed anchote tuber

Contents	Raw	Boiled - after –Peeling	Boiled – Before - peeling
Nutrients (mg/100g)			
Moisture	74.93	81.74	76.73
Cruide Protein	3.25	2.67	3.14
Ash content	2.19	1.33	1.99
Crude Fat	0.19	0.13	0.14
Crude Fiber	2.58	3.71	2.77
Utilizable Carbohydrate	16.86	10.42	15.23
Gross Energy (kcal/100g)	82.12	53.48	72.26
Minerals Content (mg/100g)			
Calcium	119.50	115.70	118.20
Iron	5.49	7.60	6.60
Magnesium	79.73	73.50	76.47
Zink	2.23	2.03	2.20
Phosphorus	34.61	28.12	25.45
Ant nutritional Factor (mg/100g)			
phytate	389	333	334
Oxalate	8.23	4.23	4.66
Tannins	173.55	102. 36	121.21
Cyanide	12.67	8.16	11.14

Source: Agren and Gibson (1968), Bradbury and Holloway (1988) cited in Abera Hora (1995), Teshome Alemayehu and Muluneh Girma (2005) and Habtamu Fekadu (2011).

2.3 Traditional ways of Serving Anchote

2.3.1 Boiled anchote tubers served as chips/slices (‘*Murmura ancootee’*/Oro.)

The tuber is sliced longitudinally into several chips and served with ‘*difo dabo*’ (Amh.) and ‘*qocqocaa*’ (Oro.), a paste of green or red pepper with pungent taste; also known as ‘*daaxaa*’ in southern Ethiopia. ‘*Qocqocaa*’ is flavored with a traditionally processed butter ‘*nitir qibe’* (Amh.) and other spices. Such chips are mainly served on special occasions such as the ‘*masqal*’(Abera, 1995).

2.3.2 Boiled anchote tubers as paste (‘*Ancootee lanqaxxii’* /Oro.).

The boiled, peeled and washed tubers are chopped into smaller pieces and ground using ‘*dhagaa daakuu’* (Oro.)/ ‘*yej wofcho’* (Amh.) - Ethiopian traditional mill. The resulting paste is flavored with processed butter and others, including salt (Abera, 1995). This is then served with ‘i*njera*’ or bread. This anchote dish is the form being served in small and large hotels and restaurants in Addis Ababa and anchote growing areas. In Addis Ababa, it is available in hotels/owned by businessmen of anchote growing area, e.g. *Hawi* Hotel around ‘*Global’*

2.3.3 Boiled anchote tubers as stew (‘*ittoo*’/Oro; ‘*wat*’/Amh.)

Boiled tubers are peeled and chopped into pieces and made into a stew, alone or incombination with legumes such as haricot beans, peas, or with meat. This is then salted, flavored and served with ‘*injera*’ (Abera, 1995).

2.3.4 Toasted tubers (‘*tibs*’/ Amh.)

Slightly boiled/unboiled and peeled tubers are chopped up and toasted using oil and a limited amount of water. This is then, served with other foods after adding the necessary ingredients (Abera, 1995). In addition to the above major anchote dishes, Abera Hora (1995) mentioned the following miscellaneous dishes.

2.4 Nutritional Composition of Soybean

Soybean (*Glycine max*) is grown in many parts of the world and is primary source of vegetable oil and protein for use in food, feed and industrial application. It is known for its relatively high protein content (about 40%) and also approximately 20% fat. Soybean is a crop capable of reducing protein malnutrition. Soybean consumption is more relatively helpful in solving nutrition protein-intake problem among the poor people. Soybean contains roughly 19% oil, of which the triglycerides are the major component. Soy oil is characterized by relatively large amounts of the polyunsaturated fatty acids i.e., ~55% linoleic acid and ~8% α-linolenic acid, of total fatty acids (Messina, 1997). Due to the presence of lipoxygenases in soybean, linoleic acid renders the soybean oil prone to rancidification (Liu, 1997). The minor components of crude soybean oil are phospholipids, collectively called lecithin, as well as phytosterols, and tocopherols.

The mineral content of soybeans, determined as ash, constitutes major and minor elements. The major mineral constitutes are potassium, calcium and magnesium. The minor constitutes comprise trace elements of nutritional importance, such as iron, zinc, copper and etc. Soybeans are known to contain a number of anti-nutritionals such as protease inhibitors, lectins, goitrogens, antivitamins, saponins, tannins, phytoestrogens, flatulence factors, lysinoalanine, allergens, phytate, soytoxin, urease, trypsin inhibitor and hemagglutinins. These substances are possibly important as a chemical defence against herbivores and pathogens.

Table 2.2: Proximate Composition of Soybeans and seed

	Protein(Nx6.25)	Lipid (%)	Carbohydrate (include fiber) (%)	Ash (%)
Whole bean	40	21	34	4.9
Cotyledon	43	23	29	5
Hull	8.8	1	86	4.3
Hypocotyl	41	11	43	4.4

2.4.1 Soybean based food products.

Soymilk is a popular soybean product rich in protein, fat and minerals. It is usually processed by soaking soybean in water, followed by milling, sieving, boiling and adding ingredients such as sugar and desired flavors to taste. A common hindrance or limitation to soymilk consumption is the beany flavor. However, research efforts have been conducted to reduce the beany flavor and obtain a better tasting and acceptable product (Omueti *et al.,* 2000). Soy cheese (tofu) is a highly digestible product that is good for people suffering from lactose intolerance. It is coagulated with some food chemical such as calcium chloride, magnesium chloride, calcium sulphate, glucono delta-lactone, or white vinegar to form curd.

Soy flour is most widely used in baked goods; 2-15% is added to breads, crackers, muffins, donuts, cakes, rolls, cookies, tortillas, or chapatis. It is also used in pasta products (spaghetti, Noodles, macaroni), processed meats (sausages, bologna, frankfurters, meat loaves), gravies, sauces, soups, cereals, prepared mixes (pancake and waffle), dairy substitutes, candies (caramels and toffees), special diet foods (diabetic, allergenic, high protein), and spice bases. In baked goods, soy flour increases the storage life and nutritional value, while adding moisture as needed with little or no increase in cost (William and Akiko, 2007).

2.5 Health and Nutritional Benefits of Oats

In fact, the health effects of oat rely mainly on the total dietary fiber and β-glucan content (Kerckhoffs *et al.,* 2003). Oat protein is nearly equivalent in quality to soy protein, which has been shown by the World Health Organization to be equal to meat, milk, and egg protein. The protein content of the hull-less oat kernel (groat) ranges from 12 to 24%, the highest among cereals (Lasztity, 1999). Oats are a rich source of soluble fiber, well-balanced proteins and several vitamins and minerals essential for the human health (Esposito *et al.,* 2005).
Oats contain relatively high amounts of lipids compared with other cereal grains with a substantial level of essential linoleic acid (Mattila *et al.,* 2005).

Additionally, oats are a source of several natural antioxidants such as tocopherols, alk(en)ylresorcinols, and phenolic acids and their derivatives, and a unique source of avenanthramides (N-cinnamoylanthranilate alkaloids) and avenalumic acids (ethylenic homologues of cinnamic acids), which are not present in other cereal grains (Mattila *et al.,* 2005). All of these phenolic compounds possess potential health-promoting properties because of their antioxidant activities and/or membrane-modulating effects (alk(en)ylresorcinols).

Moreover, β-glucans, which also exhibit an antioxidant property are included in the soluble dietary fibre fractions of oats that participates in glucoregulation and causes a decrease in serum cholesterol levels in humans (Esposito *et al.,* 2005). The consumption of oats is therefore an important component of diet for hypercholesterolemic patients (Czerwiński *et al.,* 2004). In addition to their importance in the diet, oats antioxidants may also contribute to the stability and the taste of food products. Most of the previous studies in literature have reported a good antioxidant capacity of oats (Mattila *et al.,* 2005). β-Glucan is a soluble fiber readily available from oat grains that has been gaining interest due to its multiple functional and bioactive properties.

Its beneficial role in insulin resistance, dyslipidemia, hypertension, and obesity is being continuously documented. Starch is the main storage compound in oat grains constituting 60% of the dry weight (Wood *et al.,* 1991).

Table 2.3: The general composition of whole grain oat flour and oat bran (Bruce, 2008).

	Whole grain Oat flour (%)	**Oat bran (%)**
Protein	15-17%	15-18%
Starch and sugar	59-70%	10-50%
Fat	4-9%	5-10%
Total dietary fiber	5-13%	10-40%
B – Glucan	2-6%	5-20%

2.6 Malnutrition and Protein Energy Malnutrition

2.6.1 Malnutrition

Protein Energy Malnutrition is by far the most lethal form of malnutrition. It is an imbalance between the supply of energy and protein, and the body's demand for them to ensure optimal growth and function. It is currently the most widespread and serious health problem of children in the world being moderate or severe forms (FAO/WHO, 1998 & USAID, 2002). Although infants and children of some developing nations dramatically exemplify this type of malnutrition, it can occur in persons of any age in any country. Inadequate intake of food essential nutrients leads to under nutrition, resulting in deterioration of growth and health

PEM primarily affects infants and preschool children, making it the main cause of growth retardation. About 31% of the children less than 5 years of age in developing countries are moderately to severely underweight, 39% are stunted, and 11% are wasted, based on a deficit of more than two standard deviations below the WHO/National Center for Health Statistics (NCHS) reference values (Armar, 1989). It results from inadequate intakes of protein, energy fuels, or both. Deficiencies of protein and energy usually occur together, but when one predominates and the deficit is severe, kwashiorkor (primarily protein deficiency) or marasmus (predominantly energy deficiency) ensues.

2.6.2 Energy

Energy is used for: the essential body functioning, growth, and physical activities. The total amount of energy needed by different individuals varies depending on the age, sex, body size, but especially on the amount of physical activities and extra energy is needed during pregnancy and lactation (Shimelis, 2007). The maximum food a young child can eat at a time is somewhat between 200 and 300ml. The amount energy in its food must be about 1.5-2 KCal/g. If this is not possible, the baby must be given small frequently (Shimelis, 2007).

2.6.2 Protein

Proteins are made up of building blocks called amino acids, composed of carbon, hydrogen, oxygen and nitrogen (amino group). Proteins from different food sources contain different amounts of amino acids. Proteins from animal origin, such as meat, milk and eggs, contain all essential amino acids in balanced amounts and can be judged by its ability to provide both the quantity and number of essential amino acids needed by the body.

Essential amino acids are those that the body cannot synthesis and must therefore be provided from outside. In contrast, proteins of vegetable origin (e.g., cereals and pulses) contain on their own insufficient quantities of some of the essential amino acids. By combining different foods, however (e.g., cereals with beans), adequate levels of all amino acids can be obtained without requiring protein from animal sources.

For example, the proteins obtained from wheat lack adequate quantities of one essential amino acid, and those from beans are deficient in another but the combination of cereal and pulses will provide a balanced diet (WHO/FAO, 2002). Proteins are required to build new tissue, particularly during the rapid growth period of infancy and early childhood, during pregnancy and nursing, and after infections or injuries. Excess protein is burned for energy (WHO/FAO, 2002). On the other hand, a child must have enough food in terms of both quantities and qualities. The quality of the diet depends to a large extent on the amount of protein it contains.

2.7 Complementary Foods and their Quality Attributes

Functional properties, such as solubility, gelation, viscosity, water and fat binding properties will reflect the level of protein interaction with water, while fat absorption and emulsion are influenced by protein and fat interaction. Nitrogen solubility is a good index of the functional potential of protein-rich products. CSA (2006). Viscosity is an important functional property of foods that affects mouth-feel and textural quality of fluid. Food which has shown that viscosity is a function of not only the solid concentration, but also the type of starch and protein the product bears (Shimelis A, Rakshit SK 2008). When starch granules are heated in water they swell and gelatinize forming a viscous bulky water retaining paste on cooling such thick feed, the gruel will be too thick and viscous for young infant to consume the product.
Protein concentration, especially the globulin fraction, interaction, with carbohydrate and lipids will influence the properties of protein concentrates.

This interaction is responsible for the gelation capacity of legume and oil seed protein. CSA (2006). Oil absorption is related to the physical entrapment of oil and to the number of nonpolar side chains on the proteins that bind hydrocarbon chains on the fatty acids. Water binding by protein is a function of different parameters, including size, shape, characteristics, steric factors, and hydrophilic-Hydrophobic balance of amino acids in the protein molecules, lipids and carbohydrates associated with the protein. (Shimelis and Rakshit 2008).

2.8 Product Development Principle

Product and Process Development is systematic, commercially oriented research to develop products and processes satisfying a known or suspected consumer need. The product development process include activities such as product design, process development, engineering plant design, marketing strategy and design. It is a combination and application of natural sciences with the social sciences of food science and processing with marketing and consumer science into one type of integrated research whose aim is the development of new products. The most widely referenced normative product development models are those of Booz, Allen and Hamilton Inc. (1982) and that of Cooper and Kleinschmidt (1986). The two parts of product development: the knowledge of the consumers' needs/wants and the knowledge of modern scientific discoveries and technological developments are both equally important. Four basic stages in these models for every product development process.

- Product strategy development; the project starts with the generation of new product ideas and the outlining of the product design strategy, and ends with the product concept and product design specifications.
- Product design and development; Food product development is process-intensive, process and the product are developed together.
- Product commercialization; is full scale-up of both production and marketing.
- Product launch and post-launch. There are three important parts of the launch – strategy, activities and demand outcomes.

In practice, some of the activities performed in the product development process can be truncated, or some stages can be omitted or avoided based on a company's accumulated knowledge and experience. Having defined product development it is now necessary to examine the issue of what constitutes a new or innovative product. Newness of a product may be judged differently according to those who perceive it. In the context of consumer goods such as food products, there are three groups of actors: consumers, distributors, and producers. Each have a different view of whether or not a product is new.

2.9 Traditionally Available Complementary Foods in Ethiopia

A number of researches (Ramakrishna *et al.*, 2006) have shown that a combination of cereals and legumes or tubers with fruits, vegetables and animal food rather than the single diets, can better support growth and development. The presence of non-nutrient constituents (anti-nutritional factors) in plant-based foods has been shown to also negatively influence the bioavailability of nutrients. The best documented being oxalic acid which forms oxalate precipitates with dietary calcium, while phytic acid forms insoluble phytates with Ca, Fe, Zn and possibly other metals. For instance the relatively poor availability of the fairly high Fe content of cereals is mainly due to their correspondingly high phytic acid level (Sucan, 1987).

Poor processing methods and hygiene have also been identified as other factors responsible for low nutrient density in local complementary foods due to lack of knowledge about simple processing techniques to produce nutritious food. The simple traditional house hold technologies have been used to process the cereal in order to improve the nutritional quality. These include roasting, germination or sprouting; fermentation, cooking and soaking that greatly influence their nutritive value. Of these, cooking and germination plays an important role as it influences the bioavailability utilization of nutrients and also improve palatability which can result in enhancing the digestibility and nutritive value (Mariam, 2005).

Table 2.4: Major grain traditional complementary foods

Complementary food	Raw Food Item Used
Gruel	Teff, Sorghum, Barley, Maize, Wheat, Emmer wheat and Enset
Porridge	Teff, Sorghum, Barley, Maize, Wheat, Emmer wheat and Enset
Fetfet	Teff, Sorghum, Barley, Maize, Wheat, Broad bean, chick peas, field peas and Lentil
Kitta	Teff, Sorghum, Barley, Maize, Wheat, Chick peas and Enset
Dabo	Teff, Sorghum, Barley, Maize, Wheat, and Emmer wheat

2.10 Assessment of Existing Baby Food Production in Ethiopia: the case of Faffa Food S.C

Faffa Food Share Company is one of the leading food factories in Ethiopia engaged in the production of different nutritional contents of baby foods. This company produces mainly Famix, Dube Duket, Cerifam, Edigut Milk, Faffa and others. The factory purchases its raw materials from local market and other ingredients such as vitamins, minerals, premix, milk powder, enzymes and etc from foreign market.

- Famix – can be used at all times to families, to the public, drought victims, and to vulnerable people. It is prepared from roasted maize, and roasted soya flour, sugar, vitamins (A, B1, B2, B6, B12, C, D, Nicotic Acid, Folic Acid); minerals (Iron, Iodine and Calcium).
- Dube Duket – is protein enriched wheat flour prepared from high quality wheat flour, soya flour, vitamins and minerals.
- Cerifam – is nutritionally enriched pre-cooked baby food usually for infants above age of 4 months. It is composed of wheat flour, skimmed milk powder, full fat milk, soya flour, chickpeas, sugar, vitamins & minerals and an enzymes α-amylase & vanilla
- Edger Milk – is fortified full cream powder for family. It is composed of full fat milk powder, sugar, vitamins and minerals.
- Faffa – is supplementary weaning food for infants primarily above age of 6 months. It is basically prepared from wheat flour, skimmed milk powder, soya flour, chick peas, Sugar, vitamins and minerals.

2.11 Demand Gap between the Existing Productions

The demand for industrially processed baby food is influenced mainly by the baby /infant population, income of household and urbanization. The urban population in Ethiopia is growing by more than 4%. Assuming there will be a modest growth of household income, urbanization considering the Health Extension Program in Ethiopia and programs of Non-Governmental Organizations which aims at improving infant feeding. Domestic production is assumed to remain at 38,000 tons (estimated level of production for 2012).

Table 2.5: Projected demand for Baby Food

Year	Projected demand	Existing production	Unsatisfied Demand
2013	61,660	38,000	23,660
2014	64,126	38,000	26,126
2015	66,691	38,000	28691
2016	69,358	38,000	31358
2017	72,132	38,000	34132
2018	75,017	38,000	37,017
2019	78,018	38,000	40,018
2020	81139	38,000	43,139
2021	84,384	38,000	46,384
2022	87,759	38,000	49,759

Source: Ethiopian Revenue and Customs Authority.

2.12 Effect of Processing Conditions on Anti-nutritional Factors of Complementary Food

Cooking and pre-treatment such as soaking, Dehulling, roasting, drying, germination, and fermentation can alter the content, physical–chemical properties of the components and reduce anti-nutrient level. House food processing method including soaking, roasting and germination plays an important role since it influence the bioavailability, utilization of nutrients and also improves palatability that may results in enhancing the digestibility and nutritive value (Sandberg and Andlid, 2002).

Soaking cereal and most legumes in water can result in passive diffusion of water-soluble Na, K, or Mg phytate, which can then be removed by decanting the water. A simple soaking reduce the phytate content of unrefined soybean by 50%. This is important because several recent studies in adults and infants have reported improvements in absorption of iron, zinc, and calcium in cereal-based foods prepared with a reduced phytate content. Dehulling is one of the physical treatments to remove the hulls (coats) that contain unwanted Such as tannins and high-lignin fibers present in the hull. Roasting has a significant impact on the overall quality of grain and the final product (Mridula *et al.,* 2007). Roasting consists of dry heat to the seed material by conduction or convection and heat radiations.

2.13 Physicochemical and Functional Properties

2.13.1 Physicochemical properties

- **pH of the flour**

The acidity or alkalinity of a food is usually expressed as pH. It gives us information on; to what extent a certain food sample is acidified. The pH of a food can dramatically alter the growth of microbes in food and is a major determinant of the type of food preservation process used for that food. Yeasts and molds usually grow best between pH 4 and 6 and bacteria usually grow best at pH near 7. In selecting a food preservation process that makes a food shelf stable, the initial pH of that food must be considered to minimize the likelihood of bacterial growth in that food (Mbofung, 2006).

- **Titratable acidity**

Titratible acidity measures the total amount of hydrogen ions available in the food and expressed as mg lactic acid eq/g of the food. Total acidity is the total amount of organic acids in the food sample. The titratible acidity of any food sample in the form of solution is an approximation of the solutions total acidity usually measured by reacting the acids present in the food sample with a base such as sodium hydroxide to the chosen end point close to neutrality, as indicated by an acid sensitive colour indicator (John, 2007).

2.13.2 Functional properties

Functional properties are very important in determining the level of utilization in ingredient formulation and new food product development (Fasasi, 2007). As described by Elevina E. Perez Sira, (2000), before consideration is given to tubers as potential sources of flour and starch to produce foods, it is necessary to characterize their chemical composition, physical, physicochemical, and functional properties.

The chemical composition of flours and starches exhibits differences especially in amylose and phosphorous content, as a function of the botanical origin. It is significant because of the influence of amylose and phosphorous content in the functional properties of flours and starches. It is a general consensus that the influence of both amylose and phosphorous content affects the gelatinization and pasting behavior of starches and flours. These two parameters determine the functional properties of flours and starches such as: texture, consistency, binding, adhesiveness, cohesiveness, thickening, viscosity, and palatability (Sira, 2000).

- **Water and oil absorption**

The ability of food materials to absorb water is sometimes attributed to the protein content (Mbfung, 2006). WAC is an important functional property required in food formulations especially those involving dough handling (Udensi1, *et al.*, 2008). In particular, WAC has been shown to be related to dough consistency (Njintang, *et al.*, 2008). It is known that water binding by starches and flours is a function of several parameters including size, shape, conformational characteristics, steric factors, hydrophilic hydrophobic balance in the starch molecule, lipids and carbohydrates associated with the proteins, thermodynamic properties of the system (energy of bonding, interfacial tension, etc.), physicochemical environment (pH, ionic strength, vapor pressure, temperature, presence/absence of surfactant etc.), solubility of starch molecules and others (Shimelis, *et al.*, 2006).

- **Bulk density**

Bulk density gives an indication of the relative volume of packaging material required. Generally, higher bulk density is desirable for the greater ease of dispersibility and reduction of paste thickness which is an important factor in convalescent child feeding (Udensi, and Okoronkwo, 2006)

- **Swelling Power and Solubility**

Swelling power provides evidence of non-covalent bonding between starch molecules. Factors like amylose-amylopectin ratio, chain length and molecular weight distribution, degree/length of branching and confirmation determine the degree of swelling and solubility. Solubility of flours depends on a number of factors such as sucrose, interassociative forces, swelling power, presence of other factors, etc. (Subramony, 2002).

2.14 Double Drum Dryer Equipment

Specifically in double drum dryer gelatinization takes place inside a "pool" of material formed between the drums by use of two spring loaded end plates bearing on the flat ends of the drum. The actual drying starts only after the gelatinized material leaves the pool and forms the thin film up on the surface of the drum. Film thickness control is the result of adjusting the gap between the two drums where a limitation of set by the necessity for preventing fall through of feedstock at the gap.

Depending on the design, the slurry is applied continuously as a thin film at the top of the main drum. The short exposure to a high temperature reduces the risk of damage the product and the construction of the knife holder guarantees an even pressure over the total length of the drum. The use of specific materials prevents vibrations as a result of scraping and guarantees uniform product removal. The pressure of the knife can be controlled simply and this is done outside the process area. (Rodriguez *et.al.,* 1996)

2.14.1 Drum dryer feeding methods

The method of applying sluryy onto the drum surface differs depending on the drum arrangement, the solid concentration, viscosity, and wetting ability of the product. Industrial drum dryers use five basic feeding methods, namely, roll feeding, and nip feeding, dipping, spraying, and splashing.

2.14.2 Drum dryer machine variables

- **Input variables.**

Drum speed (Vrc) and steam pressure (pv) are the most important variables of the process with regards to the final product moisture content (Xf) and outlet mass flow rate (mf). For an increase in Vrc, the influence on Xf is due to the reduction in the drying time available and change in the quantity of product smeared over the drum (Cs). Final moisture content is also conditioned by steam pressure pv: Xf obviously decreases with increase in the steam pressure (pv) due to the higher drum surface temperature. All variables induce nonlinear responses with response times and delay depending on the set points (Rodriguez *et al.,* 1995).

- **Output variables.** The most important are final moisture content Xf', which will be measured by means of product temperature (T^oC) and mass flow rate (mf) linearly depending on Cs and Vrc (Rodriguez *et al.,* 1995).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Source of Raw Materials

3.1.1 Experimental location

Sample preparation and the experiment on the Drum drying process of the product were conducted at Addis Ababa Science and Technology University. Proximate composition, vitamins, mineral and microbial contents analysis were conducted at Ethiopian Food and Drug Authority (EFDA), JIJE LABOGLASS PLC. Functional property determination and physico-chemical analysis of raw material and the developed anchote based ready to eat baby food product were conducted at Addis Ababa Institute of Technology (School of Chemical and Bio-Engineering). Protein content and anti-nutritional factors of the raw formulated flour and the developed ready to eat baby food products were determined at Addis Ababa University 4 kilo campus (Center for Food science and Nutrition).

3.1.2 Raw material collection and transportation

The raw materials were obtained from Debre Zeyit Agricultural Research Center and local markets. Anchote (from ground tuber), Soybean (from pulses) and Oat (from cereals) were selected for this study. Anchote tubers (40kg) were collected from Debre Zeyit Agricultural Research Center. Soybean (25kg) was purchased from the local market of Addis Ababa Ehil berenda, which was collected from jawi area. Oat (30kg) was collected from Oromia trade union which was collected from the farmers of Bale district. They were selected on the bases of their nutritional profile. All raw materials were harvested in the year 2018/19. Finally all the collected raw materials were sealed in plastic bag and transported to Addis Ababa Science and Technology University (Food Engineering Laboratory) and stored at room temperature till processing and analysis was conducted. Additional ingredients include sugar, water, vanilla flavor, plastic bags.

Figure 3.1 Raw anchote tuber, oat and soybean

3.1.3 Sample preparation, packaging and storage

The product was formulated by combining Anchote, Soybean and Oat flours to maximize the energy and protein content. After impurities were washed, all raw materials underwent different processing methods based on the properties of the raw materials.

A) Flour preparation from boiled anchote tuber

Boiled anchote flour was prepared based on the method described by Babajide *et al.* (2006) for yam flour preparation with some modifications. Samples were carefully selected and cleaned to remove adhering materials and soils. Then they were thoroughly washed using a running tap water. About 500g medium size samples of cleaned and washed anchote were placed in cooking utensil and 1500ml of water were added to it and the cooking utensil were placed over a hot plate to boil. The time of boiling was recorded after the water started to boiling, and allowed to boil for 2hrs until they became soften. After boiling, the water was discarded and the boiled tubers were allowed to drip dry. Then the tubers were hand peeled and sliced in to approximately 0.5mm thick and immersed into 0.5 g/100 g sodium acid pyrophosphate (SAPP) solution to prevent discoloration of the roots. The sliced anchote was placed on a stainless steel tray and allowed to dry in oven at 70^{o}C over night to a constant weight. The dried anchote chips were converted to flour using electric miller (model: A11B, Germany) and sieved to pass through 600µm sieves and sealed in plastic bags, and stored at room temperature after mixing till drum drying was conducted.

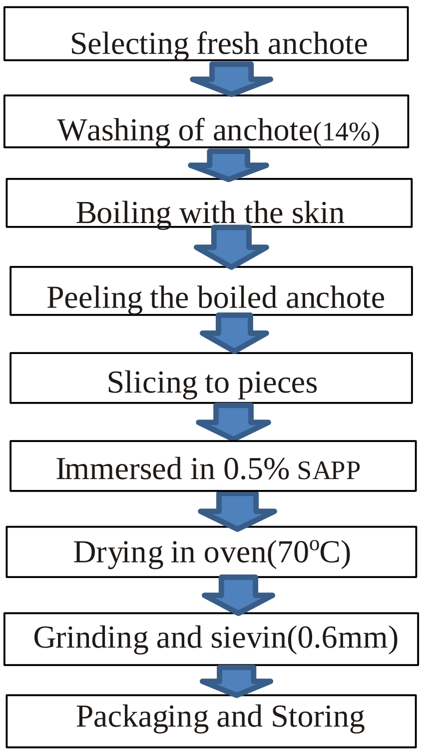


Figure 3.2 Anchote four development from boiled anchote (Babajide, *et al.* 2006)

B) Flour preparation from soybean

Defective beans (with holes), stones, dried pods and other debris were removed from soybeans. The beans were then washed and soaked in distilled water 5:1v/w for 15 h according to Assefa (2008). The soaked beans were then placed in a sieve and allowed to drain. It was then lowered into a container containing boiled water for about 20 min (Ahima, 2005). This step is called "blanching". This was done to make dehulling easier, and to inactivate enzymes' activities. The hulls were removed manually and the dehulled beans were then dried using tray dryer (Biosec dryer) until the moisture content reached 11 - 12%. Then after, it was roasted using an electric oven for 8 min at a temperature of 120 – 130ºC until it gets brown to further reduce anti-nutritive factors and improve the flavor of the final product. The roasted soybeans were milled (Retsch GmbH, West Germany, SK1) into flour to obtain smooth and consistent particle sizes and sieved through 500µm and sealed in plastic bags, and stored at room temperature till blending and formulation of flour with other ingredients was conducted. The procedure is as shown in figure 3.

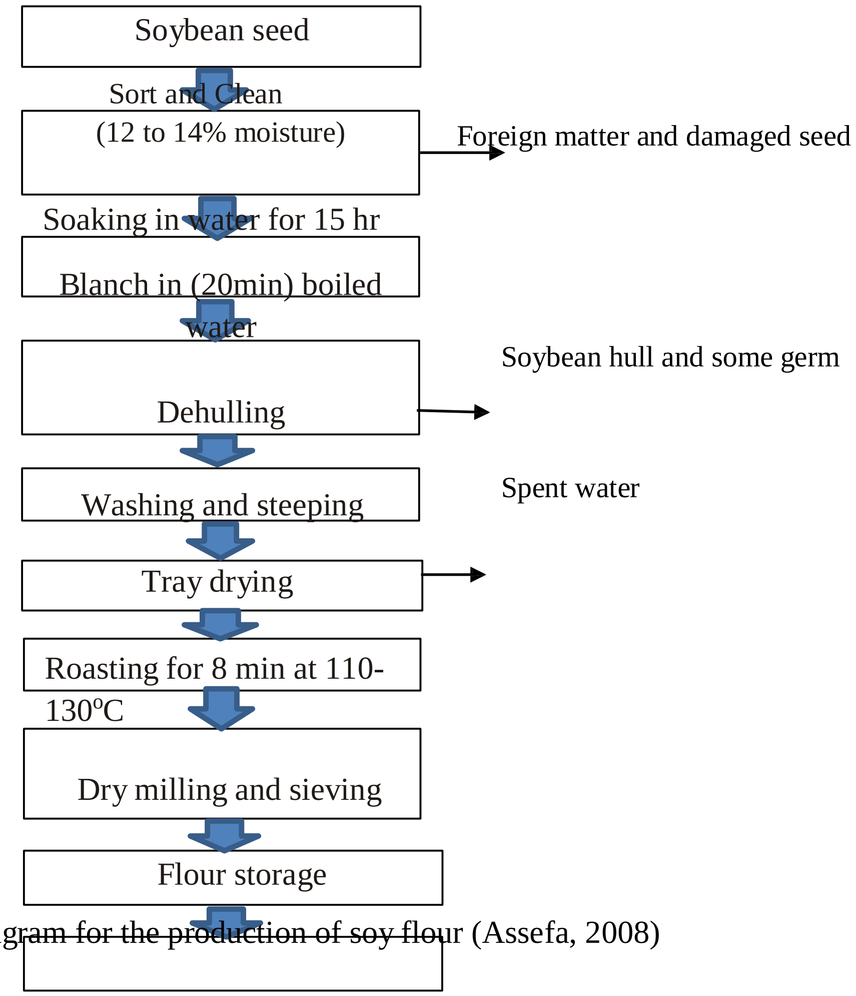


Figure 3.3 Process flow diagram for the production of soy flour (Assefa, 2008)

C) Oat flour preparation

Different impurities which came together with oat ingredients were removed manually. After impurities were removed, the oats were washed and soaked in hot distilled water for moisture adjustment and further removal of the cover. The washed and soaked oat was de-hulled and dried in tray dryer until moisture content reached 11-12%. De-hulling process also increased the nutritional value of the materials. The de-hulled oat ingredients were roasted at temperature of 140°C for 8 min. The advantage of roasting is that it increases the Maillard reaction, which is a reaction between proteins and carbohydrates that produces desirable flavours, browning and the formation of antioxidant compounds that further increase the stability of lipids (Clements & Decker, 2008). Next the roasted Oat raw materials were milled in to flour using hammer mill (Retsch GmbH, West Germany, SK1) with capacity of 600 rpm. The flour was then sifted to pass through 600µm size sieve to achieve uniform mix, sealed in plastic bags, and stored at room temperature. The procedure was shown in figure 4.

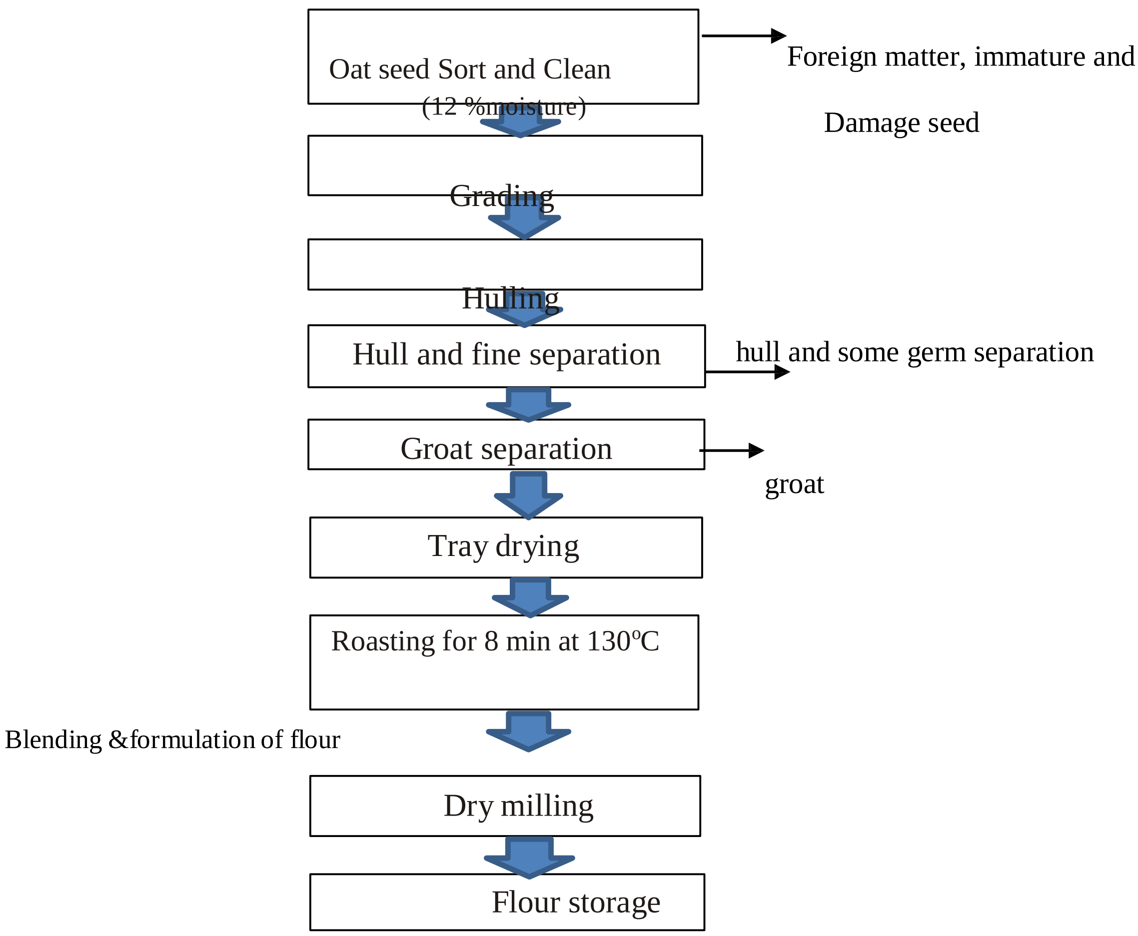


Figure 3.4 Flow diagram for the production of Oat flour (Clements & Decker, 2008)

3.2 Experimental Frame Work of the Study

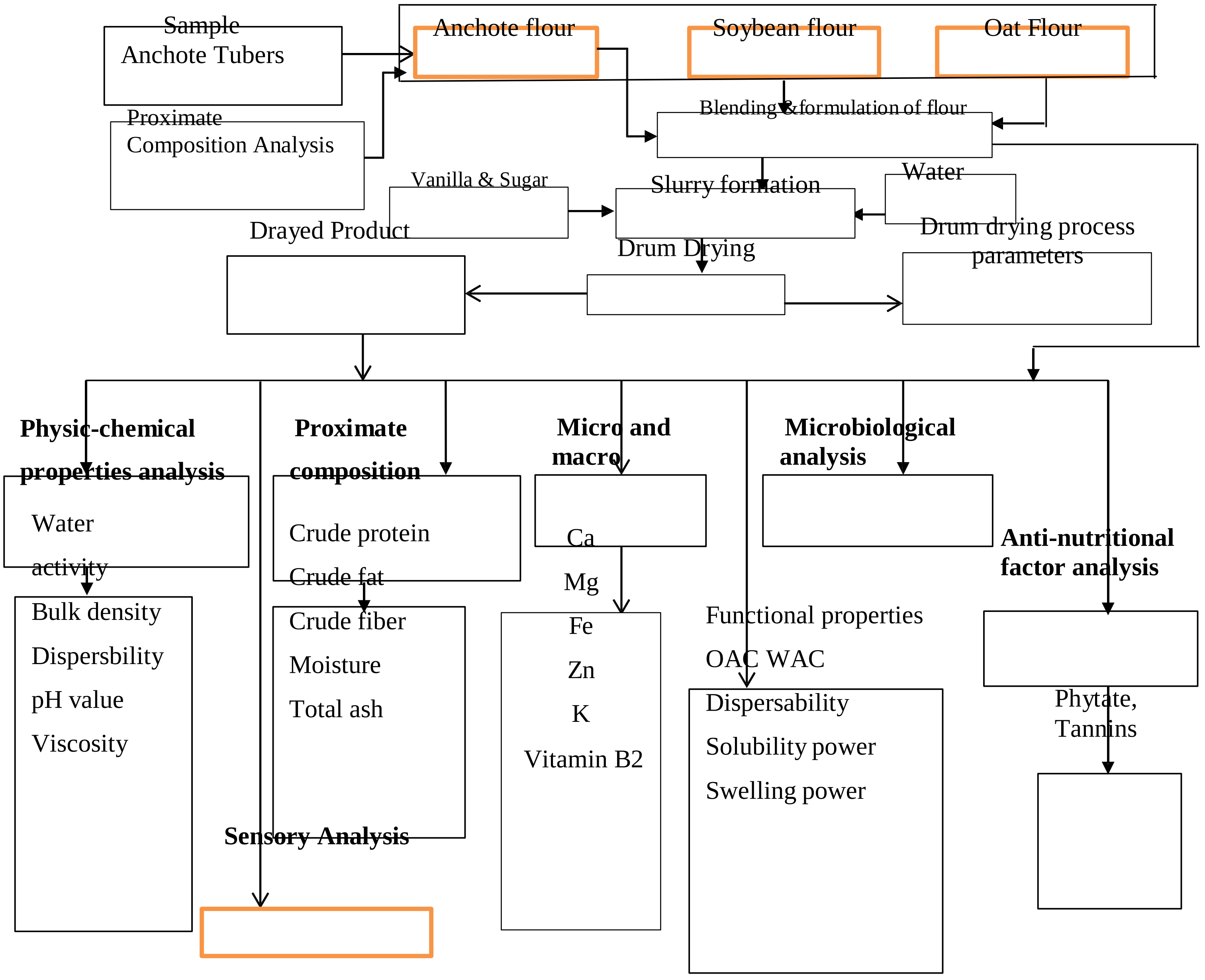


Figure 3.5: Framework of the experiment

3.3 Processing Methods

3.3.1 Blend formulation

The formulation of the three flour components for the development of baby food (complementary food) is based on the WHO standards, and the formulation was particularly for the age group of 6 to 18 months. According to WHO/FAO/ Codex Alimentarius Standards (FAO/WHO, 2004) the required daily recommended protein in the complimentary foods are ≥15%. Therefore, depending on the WHO standards the formulated flour product that contains 18% protein, 65% carbohydrates (FAO/WHO, 2004) and minimum energy value of 380 Kcal per 100g dry matter were selected according to WHP requirements. Depending on this standards D-Optimal design in the design expert (v.11.1.0) was used for the experiments as it is used for studying properties over the entire region of a three or more component mixture. Mixture Design Expert software (v.11.1.0) was used to build, test adequacy and optimize a model. In a mixture system with three components, the number of different points in D-Optimal design is analyzed. Hence, the components, in this study, were anchote, oat and soybean.

Table 3.1: Mixed components ratio of raw flour

Components	Low value	High value
Anchote	0.30	0.60
Oat	0.25	0.40
Soybean	0.15	0.30

The above low values and high values were selected due to the product characteristics and the nutritional quality of the final products. Selection of optimal mixture ratios were based on : D-optimal software, the side line activities using drum drying process, characteristics of ingredients and mixes (digestibility, starch quality), nutritional composition, product acceptability and bio availability of minerals.

The trial consisted of different proportions of components of Anchote, Oat, and Soybean with values between zero and one i.e. $0<A+B+C \leq 1$. The sum for each run of the mixture is 1 and the component values are interpreted as proportions. Therefore, flour of Ancote, Oat, and soybean were prepared according to the augmented D-optimal design with 16 points.

Table 3.2: Blend formulation in the experimental design

Run	Component 1 A:Anchote %	Component 2 B:Oat %	Component 3 C:Soybean %
1	60	25	15
2	45	40	15
3	49.5	25	25.5
4	30	40	30
5	40.4912	39.0854	20.4234
6	60	25	15
7	*54.1166*	*26.5968*	*19.2867*
8	45.0829	33.3979	21.5192
9	40.4216	29.5784	30
10	40.4216	29.5784	30
11	35.1381	40	24.8619
12	45	40	15
13	35.3132	34.6868	30
14	51.9958	33.0042	15
15	30	40	30
16	49.5	25	25.5

.
Figure 3.6 Components of blended flour

- **Model fitting**

The first step in each case was to perform ANOVA so as to select the appropriate type of model (linear, quadratic, etc.). Once a model has been fit, it was important to verify the adequacy of the chosen model quantitatively and graphically (Cristiane *et al.,* 2006). Under the "Source" column of the ANOVA table, the line labeled "Linear" indicates the significance of adding linear terms, and the line labeled "Quadratic" indicates the significance of adding quadratic terms. The column labeled "DF" shows the degrees of freedom for each source. The F-statistic is calculated for each type of model, and the highest order model with significant terms normally would be chosen. Significance is judged by determining if the probability that the F-statistic calculated from the data exceeds a theoretical value. The probability decreases as the value of the F-statistic increases. If this probability is less than 0.05, the terms are significant and their inclusion improves the model. Moreover, test statistics like adjusted R^2, predicted R^2, and prediction error sum of squares (PRESS) calculated by the Mixture Design Expert of the Statistical Analysis System software were additionally considered to choose best fit model (Ibrahim *et al*, 2010).

- **Check lack of fit**

The lack-of- fit is a measure of the failure of a model to represent data in the experimental domain, especially for those points which were not included in the regression or variations in the models and thus cannot be accounted for by random error .Once the type of model (e.g., linear, quadratic, etc.) was selected, the second step was to perform a lack-of-fit test, also using ANOVA, to compare the residual error to the pure error from replication. When residual error significantly exceeds pure error, then it was concluded that there were differences in the blends that the model cannot explain, and hence there was significant lack of fit (p-value >0.05) and selection of another model was appropriate. A model is adequate in describing the response if the lack-of-fit is insignificant.

- **Energy value calculation**

Energy value (calorific value) is quantified using an indirect calculation method. The three groups of nutrients, which provide the body with energy, are carbohydrates, fats and proteins (Gaman and Sherrington, 1986). One gram of carbohydrate (C) was assumed to give 15.71kJ energy; one gram of fat (F) 37.71kJ energy and one gram of protein (P) 16.76kJ. Therefore, determination of calorific value (kJ/100g) of dry beans was determined according to Osborne and Voogt (1978).

The energy values for one gram of the three groups of nutrients which provides the body with energy were calculated by using specific values of Atwater factors for protein, fat, and total carbohydrate as recommended by Birch *et al*. (1980).

$$\text{Energy value (kcal)} = \frac{(CP*4) + (CF*9) + (CHO*4) \text{ in kcal}}{100\text{g of the sample}}$$

Where;

P = Protein content (%).

F = Fat content (%).

C = Available total carbohydrate (%)

3.3.2 Drum drying Process

Based on the selected formulation, the samples were prepared as described in the flour formulation. The slurry of formulated flour was prepared by mixing of 1kg of formulated flour, 200g sugar, vanilla flavor with 2.5 liter of distilled water (2.5:1v/w) and it was subjected to drying test at all combinations of the operating conditions. Drying process was performed using laboratory scale double drum dryer (Model E- N0 5/5, china). The slurry was feed in to double drum dryer manually and the temperature of the drum dryer was set to 145^{o}C and 160^{o}C. The temperature of the dryer was controlled by stem pressure gage and inferred thermometer, drum speed and electrical power (current and voltage) was controlled by read on separate control panel board. The drum temperature which varied from 145^{o}C, to 160^{o}C were selected for the experiment. Drum speed set at 200 and 300 rpm and Particle size selected were 0.600mm, and 0.800mm.

Particle size selection process depends on some quality parameters. As a necessary process, controlling the particle size in the grinding and processing is of importance, as it will influence powder behaviors during storage, handling, and processing (Lee & Yoon, 2015). Powder with a larger particle size might be unwieldy for extraction and leaching, and would lengthen heat treatment for blanching and/or cooking (Barbosa-Canovas *et al*., 2005). In addition, various changes in powder color, texture, and bioactive compounds as well as taste acceptability would be also dependent on variations of particle size (Lee & Yoon, 2013; Liu *et al*., 2000; Zhu *et al.,* 2010).

Figure 3.7 Double drum drying Equipment and processing

Thus, searching for appropriate particle size for anchote based baby food would be necessary to improve the application in nutraceuticals and functional food products, as well as a potential and novel biomaterial. In contrast, Fleury and Lahaye(1991) reported that the smaller particle size of flour (Lami-naria digitata) was associated with higher water uptake and oil absorbtion capacity. Kirwan *et al.*, (1974) suggested that, in the absence of matrix structure (micro crystalline cellulose), relative surface area and the total amount of water held by fibre varies inversely with particle size.

3.3.3 Process flow diagram of anchote based ready to eat baby food

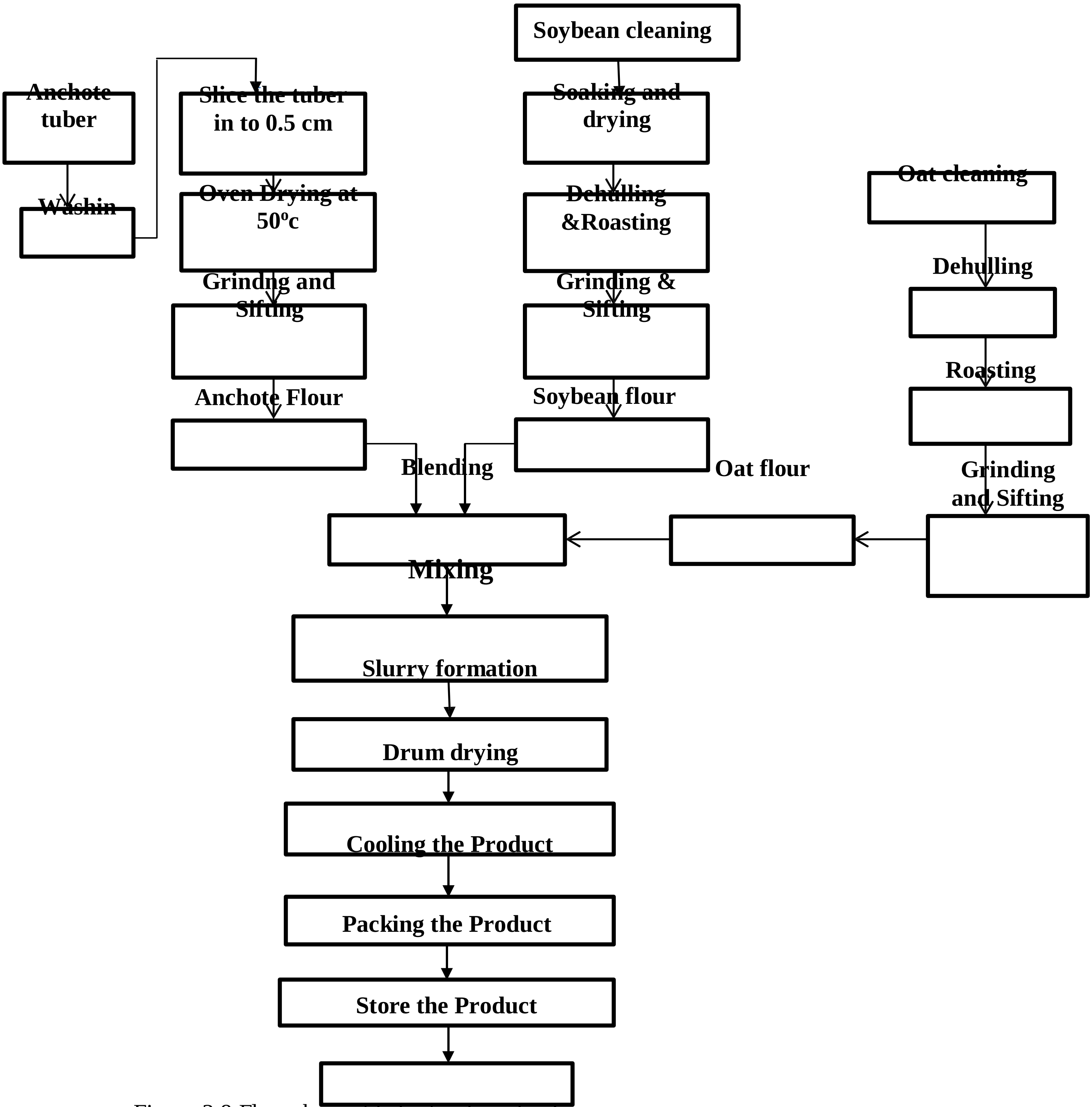


Figure 3.8 Flow sheet of baby food production

3.4 Analysis Methods

3.4.1 Proximate analysis

Proximate chemical composition analysis such as moisture content, total ash, crude protein (N*6.25), crude fiber, crude fat of Ready to eat baby food product were performed according to AOAC official methods 925.09, 900.02, 920.123, 962.09, 933.05 respectively.

- **Determination of moisture content**

Moisture was determined according to AOAC (2000) using the official method 925.09. A clean dried and covered flat aluminum dishes were weighed and about 5gm of the sample were transferred to the dish. The dish then placed in the oven (Memmert 854 Schwabach, West Germany) at 102^{o}C for overnight and cooled in desiccators and re-weighed. Then, the moisture content was estimated by the formula:-

$$\text{Moisture content (MC)} = \frac{\text{Wt before drying} - \text{Wt. after drying}}{\text{Wt before drying}} * 100$$

- **Determination of total ash**

The ash content was determined by standard AOAC 900.02 method. The porcelain dish used for the analysis was washed by dilute hydrochloric acid on boiling. And it was washed with distilled and de-mineralized water respectively. Then dried at 120^{0}C in an oven and ignited at 550^{0}C in (Carbolite, Aston Lane, Hope, Sheffield s30 2RR, England) furnace for 3 hour. The dish was then removed from furnace and cooled in desiccators. The mass of the dish was measured using (ARZ140, N315, SNR=1203290469, USA) analytical balance (M1). About 2.5 gm of sample powder was weighed in to the porcelain dish (M2).The sample was charred at 120^{0}C on hot plate (Wagtech, UK, hot plate SH3), until the whole content becomes carbonized. Then the sample was placed in a (Carbolite, Aston Lane, Hope, Sheffield s30 2RR, England) furnace at 550^{0}C until whitish color appears. The sample was removed from the furnace and placed in desiccators. Finally the mass was weighed as (M3).

$$\%\ \text{ash (Dry basis)} = \frac{(\text{Wt after ashing} - \text{tare wt of crucible})}{\text{Original sample wt x dry matter coefficient}}$$

- **Determination of crude protein**

Protein content was determined according to AOAC (2000) using the official method 979.09. A digestion flask containing about 1 g of sample, to which 6 ml of acid mixture (conc. sulphuric acid and conc. orthophosphuric acid) and about 3g of catalyst mixture (K2SO4 and Selenium) were added and exposed to about 370ºC in order to allow digestion. Then, distillation took place in Kjeltec 2300 Analyzer unit (FOSS, Sweden) by adding 25 ml of 40% NaOH and using 25 ml of boric acid with 10 drops of indicator solution. Finally, the distillate was titrated with standardized 0.1N sulphuric acid to a reddish color.

$$\% N = \frac{1.4007 * (V_s - V_b) * N \times 100}{W}$$

Where:

V_s = volume in ml of standard sulphuric acid solution used in titration of the test material

V_b = volume in ml of standard sulfuric acid used in titration for the blank Determination

N = normality of the standard sulphuric acid

W = weight in grams of test material

The conversion factor is 6.27 for anchote, which is obtained from food composition table of EHNRI. Crude protein content (%) = total nitrogen (%) × 6.27

- **Crude fat-**

Fat content was determined by AOAC 933.05 Modified Mojonnier petroleum Ether Extraction method. A clean and dried thimble containing about 5 g of dried sample and covered with fat free cotton at the bottom and top was placed in the extraction chamber. Then, extraction took place using 2055 Soxtec extraction unit (FOSS extractor, Sweden) for at least 4 hrs according to AOAC (2000) official method 4.5.01.

$$\text{Fat } \% = \frac{(\text{Wt dish + fat}) - (\text{Wt dish}) - (\text{Ave. wt blank residue})}{\text{Wt of the sample}} * 100$$

- **Determination of crude fiber**

Crude fiber analysis was conducted using the method of AOAC (2000) official method 962.09. About 1.6g weighed sample was transferred into a 600 ml beaker and about 200 ml 1.25% sulfuric acid was added and boiled for 30 minutes. Recording took place by placing a watch glass over the mouth of the beaker. After 30 minutes heating by gently keeping the level constant with distilled water, 20 ml 28% KOH was added and boiled gently again for another 30 minutes. Subsequently, washing was conducted with 1% sulfuric acid and NaOH solution. After, filtering it was then dried in an electric oven (Memmert 854 Schwabach, West Germany) at 1300C for 2hrs. Furthermore, it was cooled at room temperature for 30 minutes in a desiccators and weighed, then transferred the crucibles to muffle furnace (Carbolite Aston Lane, Hope,S20 England.) for 30 minute ashing at 550^{o}C. Finally, it was cooled again in desiccators and reweighed. The crude fiber content was determined by using the formula:-

$$\text{Crude fiber g/100g} = \frac{(W_1 - W_2)(100 - M)}{W_3}$$

Where: W_1 = Crucible weight before drying (g)

W_2 = Crucible weight after drying (g)

W_3 = Sample dry weigh (g)

M= Moisture content of the sample (%)

Utilizable carbohydrate determination

The total utilizable carbohydrate was calculated by difference with the exclusion of fiber.

Total carbohydrate (%) = 100 - (%moisture+ %Fat + %Protein + %Ash)

Total energy in kilo calories

The energy (GE) content in each sample was determined using the following formulae:

Total energy (kcal) = (9 × CF + 4 × CP + 4 × CHO)

Where: CF = crude fat content,

CP = crude protein content,

CHO = carbohydrate content

3.4.2 Determination of Vitamin B2 (Riboflavin)

The following procedure for determination of riboflavin in Complete Feeds and Premixes with HPLC was elaborated on the basis of the article published by Rubaj, *et al*., 2008.

Principle

Riboflavin was extracted from the examined feed sample with 0.1M sulphuric acid, and that solution was boiled for 15 min. at temperature from 110°C to 120°C. After cooling to the room temperature, the whole volume of hydrolysed sample was transferred to a 100 ml measuring flask. Amylase was added to the flask, which was then placed into a water bath at 45°C for 20 min. The enzymatic reaction was stopped by adding sulphuric acid. The sample solution was next chilled to room temperature, and the volume was corrected to 100 ml by adding 0.1 mol/l sulphuric acid. Afterwards, samples were mixed and filtrated. Extract clean-up was done by adding methanol to the sample and filtration through syringe filter before injection on the column. Riboflavin content was determined by high performance liquid chromatography (HPLC) with reversed-phase and usage of fluorescence detection.

Reagents and Solvents. All reagents and solvents should be of analytical grade: methanol for HPLC; sulphuric acid 0.1M, Amylase-5% w/v, acetic acid 0.05M, Sodium acetate-2M; vitamin B2 standard.

Chromatography: Column 25 cm x 4.6 mm**,** pore size 5mm, Column temperature 25 ºC, Injection 20 µl,

Stationary phase C18, Flow rate 0.8 ml/min, and Detector Fluorescence, Ex λ= 423, Em λ=521

Mobile phase (HTAA:Methanol, 83:17). *Solution A, HTAA (Sodium hexanosulfonate-5mM, triethylamine-0.13 %, acetic acid-1%)*

$$\text{Riboflavin (mg/g)} = C_x \times \frac{Vi}{Ws} \times \frac{D}{10} \times 1000$$

D = dilution sample

Ws = sample weight (g)

Vi = initial volume (mL)

Cx = Concentration of riboflavin in the sample (mg/L) obtained from the regression equation.

3.4.3 Mineral analysis

1 Calcium

The calcium, Iron, Potassium, Zinc and Magnesium content was determined according to the method of Association of Official Analytical Chemists' (AOAC, 2000) using the official method the official method Flame Atomic absorption Spectrophotometery, 923.03. The calcium content was determined according to the method of (AOAC, 2000) using the official method the official method Flame Atomic absorption Spectrophotometery, 923.03. About 1.0g sample was treated with 10ml of concentrated HNO_3 and 4 ml of 70% $HClO_4$.

The resulting solution was evaporated to a smaller volume (7ml) by careful heating and transferred to 50ml volumetric flask. About 1ml of $SrCl_2.6H_2O$ was added and made up to volume with distilled water. The solution was sprayed into atomic absorption spectrophotometer (Perkin Elmer, 5100 PCAAS, USA) at 422.7nm to determine calcium. The Ca standards used were 0ppm, 5ppm, 10ppm, 20ppm and 30ppm.

2 Potassium

Potassium was determined according to the method of Association of Official Analytical Chemists' (AOAC, 2000) by using the official method Flame Atomic absorption Spectrophotometery, 923.03. About 1g of the samples was dry ashed in a muffle furnace (Muffle furnace size 2, England) at 550°C for 5 hours until a white residue of constant weight was obtained. The mineral was extracted from the ash by dissolving the ash in 10 ml HCl solution (1:1, HCl: H_2O). Ashed sample diluted to 25 ml, then 0.2 ml diluted to 100 ml and stored in clean polyethylene bottles and potassium content was determined using atomic absorption spectrophotometer (Perkin Elmer model 5100 PCAAS, USA) at 285.2nm.

3 Iron

The iron content was determined based on the method described by the method of Association of Official Analytical Chemists' (AOAC, 2000) using the official method Flame Atomic absorption Spectrophotometery, 923.03. 10ml of concentrated HNO_3 was added to about1g of the sample and left overnight. The sample was carefully heated until the production of red nitrogen dioxide fumes ceased. The sample was cooled and 4ml of 70% $HClO_4$ was added and evaporated to a smaller volume (7ml) by careful heating. The resulting solution was quantitatively transferred into 50ml volumetric flask and diluted to the mark with distilled water. The solution was sprayed into an atomic absorption spectrophotometer (Perkin Elmer, model 5100 PCAAS, USA) at 248.3nm to determine the concentration of iron. The iron standards used were 0ppm, 1ppm, 2ppm, 3ppm and 4ppm

4 Zinc

Zinc determination was done based on the method determined according to Association of Official Analytical Chemists' (AOAC, 2000) using the official method Atomic Absorption Spectro photometery, 923.03. The ash obtained after dry ashing at 525$_o$C was treated with7ml of 6N HCl to wet it completely and 15ml of 3N HCl was added and the dish was heated on the hot plate until the solution just boils. Then, it has been cooled and filtered. 10ml of 3N HCl was added to the dish and heated until the solution just boils. Finally, filtered into the flask.

Using atomic absorption spectrophotometer (Varian, spectra-10/20, Australia) a calibration curve was prepared by plotting the absorption or emission values against the metal concentration in mg/100g for all of the above minerals. Thus reading was taken from the graph which depicted the metal concentrations that correspond to the absorption or emission values of the samples and the blank. The metal contents were calculated by using the formula:-

$$\text{Metal Content (mg/100g)} = \frac{(A - B) \times V}{10W}$$

Where, W = Weight of sample in (g)   V = Volume of extract (ml)

A= Concentration of sample solution (μg/ml)   B = Concentration of blank solution (μg/ml)

3.4.4 Physico-chemical properties

1 Water activity analysis

The water activity of the product will be determined using Aqua Lab Lite water activity measuring unit manufactured by Decagon a_w meter, (2004). Each sample will be half filled in a small plastic cup supplied with the instrument and inserted in to the instrument then the water activity of each sample will be displayed automatically.

2 Determination of viscosity

The viscosity of cooked paste was determined with a Vibro Viscometre (SV-10, Germany). A 10% slurry (dry matter basis) of each flour was prepared with 200 ml distilled water and the Slurry was heated uniformly from 25°C to 95°C and held for 15 min and cooled to 50°C. Then Viscosity on cooling to 50°C was determined (Mbata *et al.,* 2009).

2 Determination of pH value

The pH of the raw and processed samples was determined according to the method of AOAC (1984). About 10 g of the samples were weighed in triplicates in 250ml beaker and mixed with 50 ml of distilled water and stirred for 10 min. The pH of the sample was determined by dipping the electrode of the Jenway pH meter (Jenway 3510 pH meter) in the mixture. The pH meter were calibrated using pH 4.0 and 7.0 buffers prior to determination of the pH of the samples.

3 Bulk Density

The method used by Udensi & Okaka (2000) was adopted for determination of the bulk density of the samples. Fifty ml graduated cylinder containing 5 g of anchote powder sample was tapped continuously against the palm of hand until a constant volume was obtained. The volume was used to calculate the bulk density with the following formula:

$$\text{Bulk density } (g/cm^3) = \frac{\text{Weight of Sample}}{\text{Volume of sample}}$$

3.4.5 Functional properties of the product

i) Water and Oil Absorption Capacity (WAC and OAC)

Water and oil absorption capacity were determined according to Gandhi & Srivastava (2007). One gram of sample was mixed with 10 ml distilled water and sunflower oil respectively in centrifuge tubes, and then allowed to stand for 30 min. Samples were centrifuged at 3000rpm for 30 min. Weight of the tube was measured after discarding the supernatant. Results were reported by taking the average of 10 measurements. The WAC (grams of water per gram of sample) and OAC (grams of oil per gram of extract) was calculated using the following equations:

$$\text{Water Absorption Capacity (WAC)} = \frac{(W_2 - W_1)}{W_0}$$

Where:

W_0: Weight of the dry sample

W_1: weight of tube plus dry sample

W_2: weight of tube plus sediment

Oil Absorption Capacity (QAC) = $\frac{(F_2 - F_1)}{F_0}$

Where:

F_0: Weight of dry sample (g)

F_1: Weight of tube plus dry sample (g)

F_3: Weight of tube plus sediment (g)

ii) Swelling power and solubility

Swelling power and solubility determinations were carried out in the temperature range of 60-90°C (using the method of Leach *et al.*, 1959*)*. About one gram of anchote flour sample was accurately weighed and quantitatively transferred in to a clear dried test tube and weighed (W_1). About 15 ml of distilled water were added and mixed gently at low speed for 5 min. The slurry was heated in a thermo stated water bath, at 80°C for 30 min with mixing the suspension intermittently. The test tube was cooled with its content rapidly to 20°C. During heating, the slurry was stirred gently to prevent lumps forming in the flour. Then the cool paste was centrifuge at 2200rpm for 15 min. The supernatant was decanted immediately after centrifuging into a pre-weighed evaporating can and dried at 100°C to constant weight approximately for 4 hours. The weight of the sediment was taken and recorded as (W_2) or swollen mass suspension intermittently.

Swelling power = $\frac{\text{Wt of sediment}}{\text{Sample wt – wt of soluble}}$

Solubility index (%) = $\frac{\text{wt soluble x 100}}{\text{Wt of sample}}$

iii) Dispersibility of flour blends

Dispersibility in water which indicates their ability to reconstitute was determined by the method of Kulkarni et al. (1991). 10 g of each flour sample were weighed into a 100 ml measuring cylinder. Distilled water was added up to 100 ml volume. The sample was vigorously stirred and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100 to give a difference that is taken as percentage dispersibility.

3.4.6 Antinutrient analysis

1. **Analysis of phytate**

The phytate content in the sample was determined according to the method described by Latta and Eskin (1980), and later modified by Vaintraub and Lapteva (1988).About 0.05gm of dried sample was extracted with 10ml 2.4% HCl in methanol for 1 hr at ambient temperature and centrifuged (3000 rpm) for 30 minutes. The clear supernatant was used for the phytate estimation. About 1ml of wade reagent (0.03% solution of FeC13 water) was added to 3ml of the sample solution and the mixture was centrifuged.

The absorbance at 500ηm was measured using spectrophotometer calculated from the difference between the absorbance of the control (3reagent) and that of the assayed sample. The concentration of phytate was calculated using acid standard curve and the weight. To prepare the phytic acid standard curve, a series of standard solution was prepared containing 5–40 mg/ml phytic acid in water. About 3ml of the standards was pipetted into 15ml centrifuge tubes with 3ml of water used as a zero level. To each tube was added about 1ml of the wade reagent, and the solution was mixed on a vortex mixer for 5s. The mixture was centrifuged for 10 min and the supernatant read at 500ηm was read by using water as a blank.

2. **Tannin Analysis**

Tannin determined by the modified Vanillin assay (Butler *et al.*, 1982). About 200mg ground bean was weighed and then extracted with 10 ml absolute methanol for 20 min in rotating screw cap culture tubes. The mixture then centrifuged (Nüve, bench-top centrifuge, NF 800R, 2001, Ankara,Turk) for 10min at 3000 x G and the supernatant was used in the analysis. About 0.0 - 1.0 ml aliquots of catechin standard was dispensed into two sets of culture tubes and each sample was brought to 1.0 ml by the addition of absolute methanol.

Incubate the tubes in the water bath (BüCHI water bath B-481, BüCHI, Switzerland). 5 ml of the working vanillin reagent was added at 1min interval to one set of standards, and 5 ml of the 4% HCl solution was added at 1min intervals to the second set of standards. The samples in a water bath were kept for exactly 20 min, and then removed and the absorbance at 500nm was read using spectrophotometer (BECKMAN, DU-64, Japan).

The absorbance of the blank was subtracted from the absorbance of the corresponding vanillin-containing sample. A standard curve has been constructed (Absorbance vs. catechin) and the linear portion of the curve was extrapolated to produce the standard curve. Finally, the tannin contents were calculated. Values of tannins were expressed in miligram of D-catechin equivalent per gram of sample.

$$\text{Tannin mg/g} = \frac{[(As - Ab) - \text{Intercept}] \times 10}{\text{Slope} \times d \times W}$$

Where

As = Sample absorbance

Ab = Blank absorbance

d = density of solution (0.791g/ml)

w = weight of solution in gram

3.4.7 Microbiological analysis

Determination of Mold and Yeast was conducted using NMKL, No. 98, 1997 method (Appendix-D). Aerobic Plate Count (APC) was determined as to NMKL, No. 86, 2006 (Appendix-E). Coliform count was carried out according to NMKL, No. 44, 2004 (Appendix F). Fecal coliform count and E. coli was determined by FDA/BAM, 2006 (Appendix-XII).

3.4.8 Sensory analysis

A well-known instant baby food (Cerefam) which is the products of Faffa food S.C was used as the control sample in this study and as such included in the sensory evaluation.

Preparation of sample: - Two hundred fifty milliliters of water at 85ºC was added to 100 g of the processed. Anchote-based instant complementary food flour and stirred with a wooden ladle consistently until a paste was formed. These food samples were served in disposable cups in a random order for panelists to assess. The sensory evaluation was carried out in a sensory lab (a closed room) in the Faffa Food S.C. The sensory lab had adequate lighting from daylight or the sunlight and panelists were seated in individual booths. The prepared gruels was served to the panelists in white plastic cups at about 40^0C. Sensory analysis; color, appearance, texture, aroma and overall acceptability of the Anchote based ready to eat Baby food product was evaluated by 20 panelists selected from Faffa Food Share Company.

From twenty panelists, 12 panelists were trained employers of the company and 8 of the panelists were Food Engineering students from different universities on apparent ship in that company. They were instructed to evaluate color first and then to observe each sample to evaluate appearance, aroma texture and overall acceptability. A nine point Hedonic scale with 1=Dislike extremely, 5= neither like nor dislike, 9=Like extremely was used for all attributes measured. Samples were randomly presented for the panelists to minimize the effects of uncontrollable sources of variation or error and to eliminate bias. Data for the responses for the sensory attributes was analyzed using ANOVA to determine the mean of treatments, panelists and their significance at 0.05% of significant level. (Watts *et al.*, 1990).

3.5 Experimental Design and Statistical Analysis (Software)

The experiment was analyzed by Response Surface Methodology (RSM), with three variables using a mixed 2x2x2 full factorial. Experimental design was used to study the effect of drying operating conditions and raw material characteristics on product quality attributes. The factors that affect drum dryer with levels are drum temperature with two levels (145 & 160^{o}C), drum speed with two levels (200, & 300 rpm) and particle size distribution with two levels (0.600mm & 0.800mm). Therefore, using these variables with respective levels, full factorial design treatment was used for flour of blends.

All statistics mean comparison analysis were performed using Minitab statistical software version 17.1.0. Significance was accepted at 0.05 level of probability ($p < 0.05$). One way ANOVA (analysis of variance) were used for comparison of means. Mean separation was performed by LSD (least significant difference) for multiple comparisons of means. Design expert software version (11.1.0) was used to show the effect of drum drying conditions and raw material characteristics on product quality attributes. The response variable was energy and protein content. Significance of the result is set from analysis of variance (ANOVA). Two levels, three factors CRD was used to optimize the process, this need 16 experiments that has been done.

The drying variables studied were drum drying temperature (145^{o}C and 160^{o}C), drum speed (200rpm and 300rpm) and product particle size (0.600 and 0.800mm) each varied at different levels. The independent variables were selected to optimize the conditions for the development of instant baby food product.

The data required to optimize the process conditions for the development of instant complementary food was collected by conducting the sixteen experiments; analyzed by the Design Expert software (version 11.1.0) The experimental work was randomized in order to minimize errors. Although, the models (polynomials) are slightly different for the classical mixture approach and the factorial approach, many of the steps involved in model selection and fitting are the same. The first step in each case is to perform ANOVA to select the appropriate type of model (linear, quadratic, etc.). The polynomial models described in data analysis part were fit to data using analysis of variance (ANOVA) and least squares techniques (Ibrahim, et.al, 2010) of Mixture Design Expert of the Statistical Analysis System software.

Once a model is fit, it is important to verify the adequacy of the chosen model quantitatively and graphically (Cristiane *et al.,* 2006). The data obtain from the experiment were analyzed using Mixture Design Expert Software (11.1.0) of the Statistical Analysis to determine the regression coefficients and mathematical model, which is brought down to constructing a regression model and an analysis of the obtained response surface.

CHAPTER FOUR

RESULTS AND DISCUSION

4.1 Flour Yields of Anchote, Oat and Soybean

Weight of Anchote, oat and soybean after drying and milling were 7.5 kg, 5.24 kg and 4.8 kg, respectively. Oat had the highest yield (87%) followed by soybean (68.57%) and anchote (18.75%). Anchote had the least yield due to the large amount of water, typical of most roots and tubers (Ogunlakin *et al*, 2012). Fresh Anchote tuber could have a moisture content of about 75.90% (Yenenesh, 2016). Cereals and legumes on the other hand are usually dried before storage and sale; therefore, there was no much water to lose before milling. Soybean had a lesser yield compared to oat due to the dehulling process. Dehulling of soybean is necessary in the development of an infant food because the seed coat has a lot of antinutrients such as trypsin inhibitors, tannins, phytates and more.

4.2 Chemical Composition of Raw Materials (flours)

Proximate composition of raw materials (Anchote, Soybean, and Oat) such as moisture, protein, fat, ash, fiber, and carbohydrate are studied and presented in Table 4.1. Values except moister are expressed in dry matter bases, significant differences were observed at $P < 0.05$ in the nutrient contents.

Table 4.1: Chemical composition of raw materials and formulated flours

Raw material	Moisture (% Wb)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	CHO (%)	Energy(kcal/ 100g)
Anchote	$5.93±0.021^a$	$11.98±0.04^d$	$0.75±0.03^d$	$5.84±0.042^a$	$5.91±0.02^a$	$70.98±0.75^a$	$338.2±2.5^d$
Oat	$4.91±0.029^c$	$13.9±0.02^c$	$4.56±0.06^c$	$2.79±0.014^c$	$4.80±0.02^c$	$74.22±0.32^c$	$392.7±2.2^b$
Soybean	$4.64±0.012^d$	$40.5±0.65^a$	$22.4±0.11^a$	$5.69±0.021^a$	$3.98±0.05^d$	$27.1±0.014^d$	$471.8±0.8^a$
Formulated flour	$5.27± 0.04^b$	$18.3±0.02^b$	$5.65±0.04^b$	$4.25±0.14^b$	$5.18±0.16^b$	$63.14±0.07^b$	$382.1±1.5^c$

$^{a-d}$ Means with the same superscript letters within a column are not significantly different ($p>0.05$)

All values are means of triplicate ± standard deviation.

The value of moisture, crude protein, crude fibre, ash and fat contents of anchote flour were 5.93, 11.98, 5.91, 5.84, and 0.75 respectively and the result of values were consistent with the range of those reported by Yenenesh, (2016). The carbohydrate contents of the anchote flour obtained from the experiment was 70.98 and this value was disagree with the values of 73 – 84.51% reported by Yenenesh, (2016), and Habtamu (2015)

Soybean flour presents 4.64% moisture, 40.53% crude protein, 22.42% crude fat, 5.69% ash 3.98 fiber and 27.1% carbohydrates. Among the raw material flour of anchote, oat and soybean, Soybean powder has the highest crude protein, crude fat and gross energy with the value of 40.53%, 22.42% and 471.8kcal/100g respectively. The moisture, protein, fat, fiber and ash content of raw Oat flour was 4.91, 13.93, 4.56, 4.8 and 2.79% respectively. The value of protein content of oat flour reported in current study was different from the reported range of 15–20% (Robbins *et al.,* 1971; McMullen, 1991). The fat content of raw oat flour is 4.56 and this also different from the range reported 5–9% (Sahasrabudhe, 1979; Youngs, 1986; Saastamoinen *et al.,* 1989). The dietary fibre content of the oat flour difrent from the range reported 5-9% (Peterson, 2001).

The concentrations of raw materials proximate composition varied. Moisture of the flour varied from 4.64 (soybean) to 5.93 g/100 g (anchote), crude fat from 0.75 g/100g (anchote) to 22.42 g/100 g (soybean), crude protein from 11.98 (anchote) to 40.53g/100 g (soybean), total ash from 2.79g/100g (Oat) to 5.84 g/100 g (anchote), crude fiber from 3.98 (soybean) to 5.91 g/100g (anchote)and total carbohydrate from 27.1(soybean) to 74.22 g/ 100 g (oat), and finally energy from 338.2 (anchote) to 471.8 (soybean) kcal were observed. The results showed that there was significant difference ($P < 0.05$) in the proximate composition and energy values (kcal/100g) within samples.

The proximate composition of formulated raw flour for moisture, protein, fat, fiber, ash and carbohydrates ware 5.27, 18.03, 5.65, 5.48, 4.25 and 63.14g/100 respectively. The energy value of formulated raw flour was 382.1 kcal. There was significant different ($P < 0.05$) between formulated raw flour and each raw ingredient flour.

4.3 Functional Properties of Raw Materials and Formulated Flour

WAC, an indicator of the ability of flour to absorb water, depends on the availability of hydrophilic groups which bind water molecules and on the gel-forming capacity of macromolecules. WAC is the measure of the swelling power of the starch (Kite *et al.*, 1957: Anderson et al., 1996). Water Absorption capacity (WAC) characterized how the products will interact with water and are often important in predicting how the formulated complementary food products may behave if further processed. Also the degree of conversion of starch from granule during processing can be accessed via WAC (seriburi *et al.,* 1999).

Table 4.2: Functional property result of raw materials and formulated flours

Parameter	B. densi (g/mL)	WAC(mL/g)	OAC(mL/g)	Dispersib(%)	Swelling power	Solubility (%)
Anchote	0.79 ± 0.014^{a}	2.65 ± 0.14^{b}	1.14 ± 0.014^{b}	61.5 ± 0.32^{a}	6.78 ± 0.09^{a}	43.9 ± 0.42^{a}
Oat	0.70 ± 0.024^{b}	2.70 ± 0.08^{b}	0.14 ± 0.010^{d}	64.2 ± 0.50^{a}	3.69 ± 0.22^{c}	16.8 ± 0.63^{b}
Soybean	0.57 ± 0.017^{c}	3.40 ± 0.077^{a}	0.46 ± 0.005^{c}	57.2 ± 0.60^{b}	4.66 ± 0.07^{b}	17.5 ± 0.23^{b}
Formulated raw flour	0.66 ± 0.017^{d}	1.26 ± 0.021^{c}	1.41 ± 0.009^{a}	54.6 ± 1.40^{b}	3.29 ± 0.02^{c}	42.8 ± 0.042^{a}

$^{a-c}$ Means with the same superscript letters within a column are not significantly different ($p>0.05$)

All values are means of triplicate ± standard deviation

Functional properties of the raw materials and formulated flour was studied and presented in table 4.2. As observed from the table the bulk density of anchote flour had higher value (0.79g/ml) than oat, soybean and raw formulated flour, 0.70g/ml, 0.57g/ml and 0.66g/ml respectively. High bulk density of a powdered food is desirable for packing, since it allows more weight to be contained in a limited volume. Soybean had highest water absorption capacity (3.40g/ml) than anchote (2.65ml/g), oat (2.70ml/g) and formulated flour (1.26ml/g). Formulated flour has the lowest WAC value (1.26ml/g), this result is due to the combination of different ingredients with different water absorption capacity. WAC depends on the availability of hydrophilic groups which bind water molecules and on the gel-forming capacity of macromolecules.

The formulated flour has highest OAC (1.41ml/g) than each ingredient flour. The OAC of anchote, oat, and soybean were 1.14ml/g, oat 0.14ml/g, and soybean 0.46ml/g respectively. Oat has the highest dispensability (64%) value than the others and formulated raw flour has lowest despersiblity value (54.6%). The highest swelling power was observed for anchote flour (6.78) followed by soybean (4.66), oat (3.69) and raw formulated flour (3.29) respectively. There was significant different ($P < 0.05$) between dispersiblity of each ingredients and formulated flour. Anchote had highest swelling power (6.78 than oat (3.65), soybean (4.59) and formulated flour (3.29). The formulated raw flour from each ingredients had lowest swelling power (3.29) and this result may be due to the mixing proportion of highest and lowest swelling power of each ingredients used in the formulations.

Anchote flour had highest solubility power 43.9% than the others and the solubility value of oat, soybean, and formulated flour were 16.8, 17.5 and 42.8% respectively. Oat had lowest solubility value (16.8%) than the others. There was significant difference ($P < 0.05$) between the water solubility of each ingredients and also the raw formulated flour. Anchote which had highest bulk density, swelling power and highest solubility than all ingredients and formulated flour. Swelling capacity, bulk density, dispersiblity and solubility vary significantly among the raw materials flour. Soybean had the highest water absorption capacity and Oat had highest dispersion capacity. There was significant different ($P < 0.05$) between the functional properties of each raw ingredients flour and the formulated raw flour.

4.4 Optimization of Blend Formulation Using Mixture Design

Graphical optimization was carried out for the process parameters for the preparation of ready-to-eat baby food. Design Expert program (version 11.0) of the STAT-EASE software (2018) was used for optimization of the responses.

4.4.1 Graphical optimization

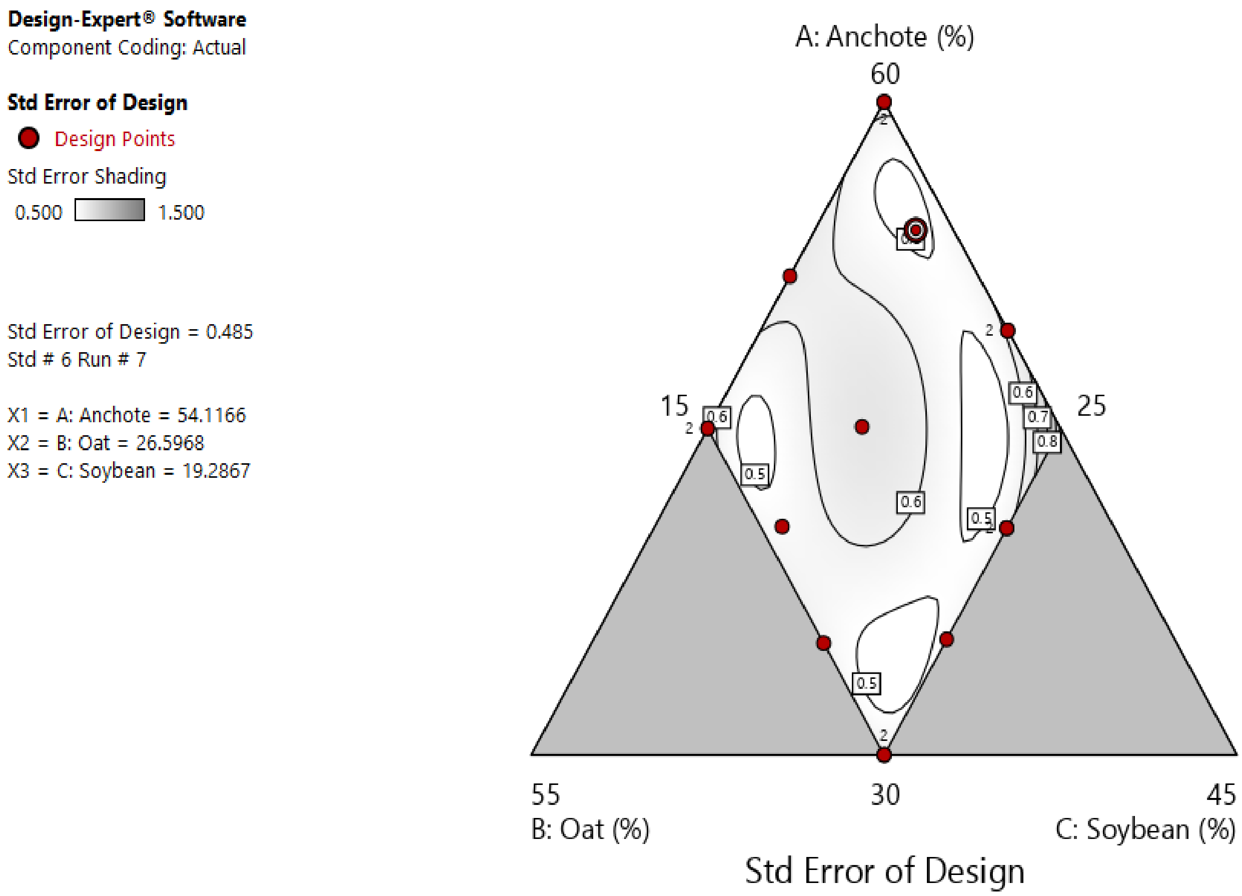
Desired goals were assigned for all the parameters for obtaining the numerical optimization values for the responses. The significance varies from smallest important to the greatest important as per the default settings. The mixture Design expert software allows to find maximally desirable solution quickly by numerical optimization. Desirability ranging from 0-1 were set for all responses to combine individual desirability's into a single number of greatest desirability. 1 value was the most appropriate response case while 0 point to that one or more responses fall outside of desired limits. Accordingly, "Goal" has been given on the basis of desired response. Anchote, Soybeans and Oat value were set in range.

Table 4.3: For variables and components

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:Anchote	54.1166	30	60	1	1	3
B:Oat	26.5968	25	40	1	1	3
C:Soybean	19.2867	15	30	1	1	3
Protein	18.01	15.91	20.06	1	1	3
Energy	380.03	359.77	382.61	1	1	3

The goal of these research was to develop anchote based ready to eat baby food (instant complementary food) that based on WHO/FAO standards of protein and energy contents of the complementary food product for the targeted age group. Codex/WHO/FAO 2004 the required daily recommended protein in the complimentary food are ≥15%. Therefore, the target was to develop anchote based ready to eat baby food product that contains 18% protein and minimum energy value of 380Kcal per 100g dry matter according to WHP requirement specifications in the weaning blend formulation for particularly the age group of 6 to 18 months. The probability of selecting a formulation with high content of protein is limited with the energy content of the final product. The Design Expert software D-optimal methods generate solutions with many mixing ratios. The mixture software generates 16 solution which can be the best and it contains overall desirability and responses variables without any effects. From the results obtained from the design expert soft were solutions with high desirability become best solution and the desirability solutions were found in appendix II.

Consequently, the formulation which contained 54.1166 % Anchote flour, 26.5968 % Oat flour and 19.2867% Soybean flour which will contribute approximately 380.03kcal Energy and 18.01% protein was selected. The Design Expert Software delivers counter plots on the 3-dimentional triangle of response variables (Energy and protein) and overlay plot. The contours are plotted and indicated a region that best predicts the pre-defined responses. Where A, B and C are Anchote, Oat and Soybean respectively.



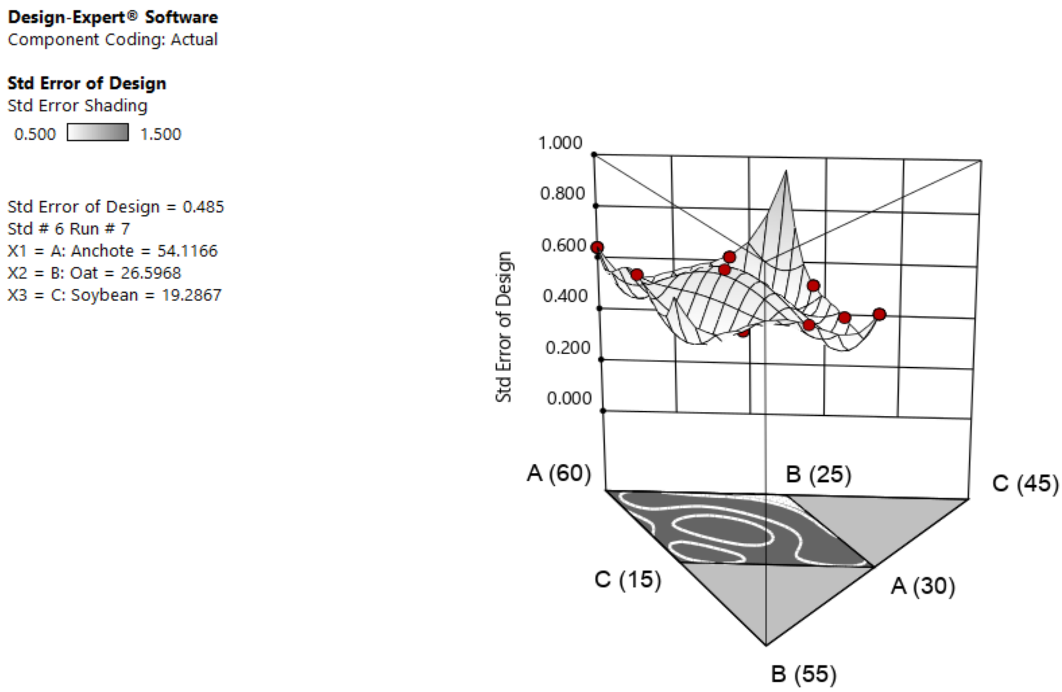
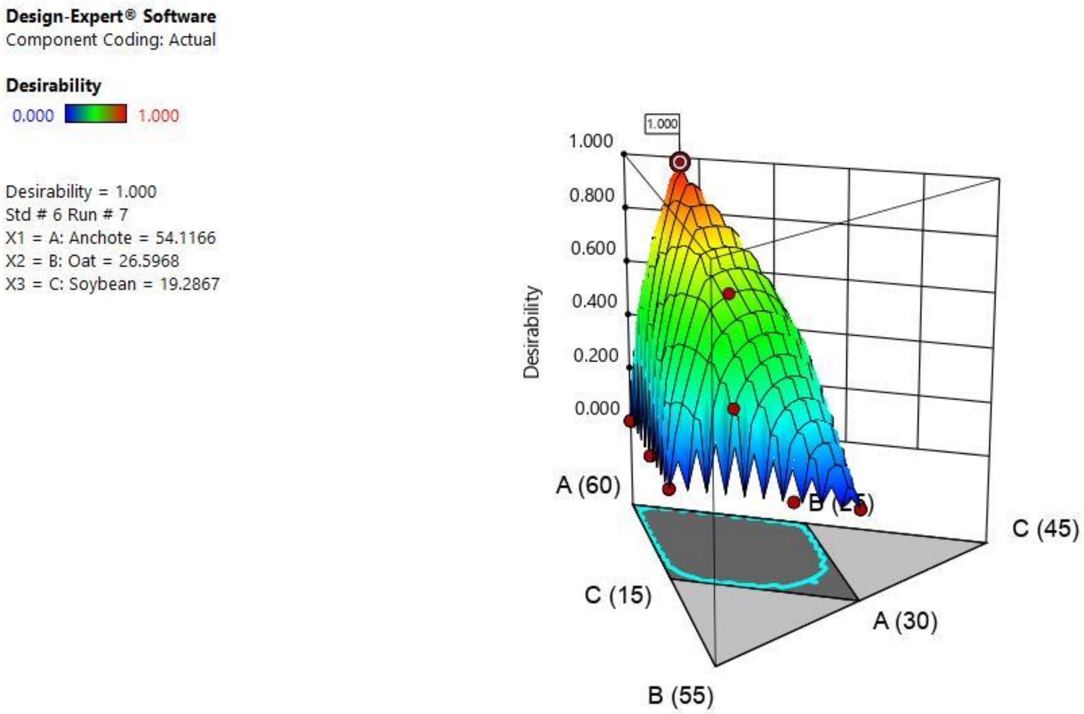


Figure 4.1 standard Error of the design



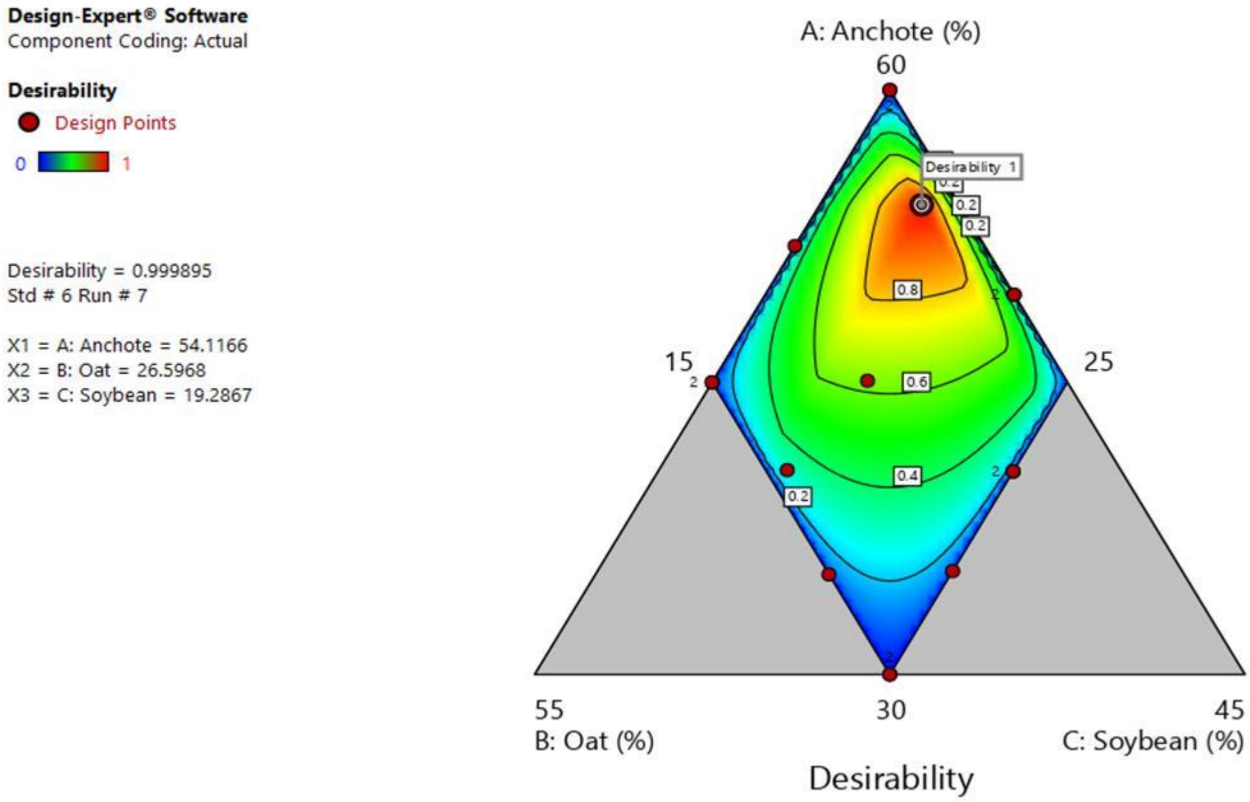


Figure. 4.2 Desirability (3D and contour)

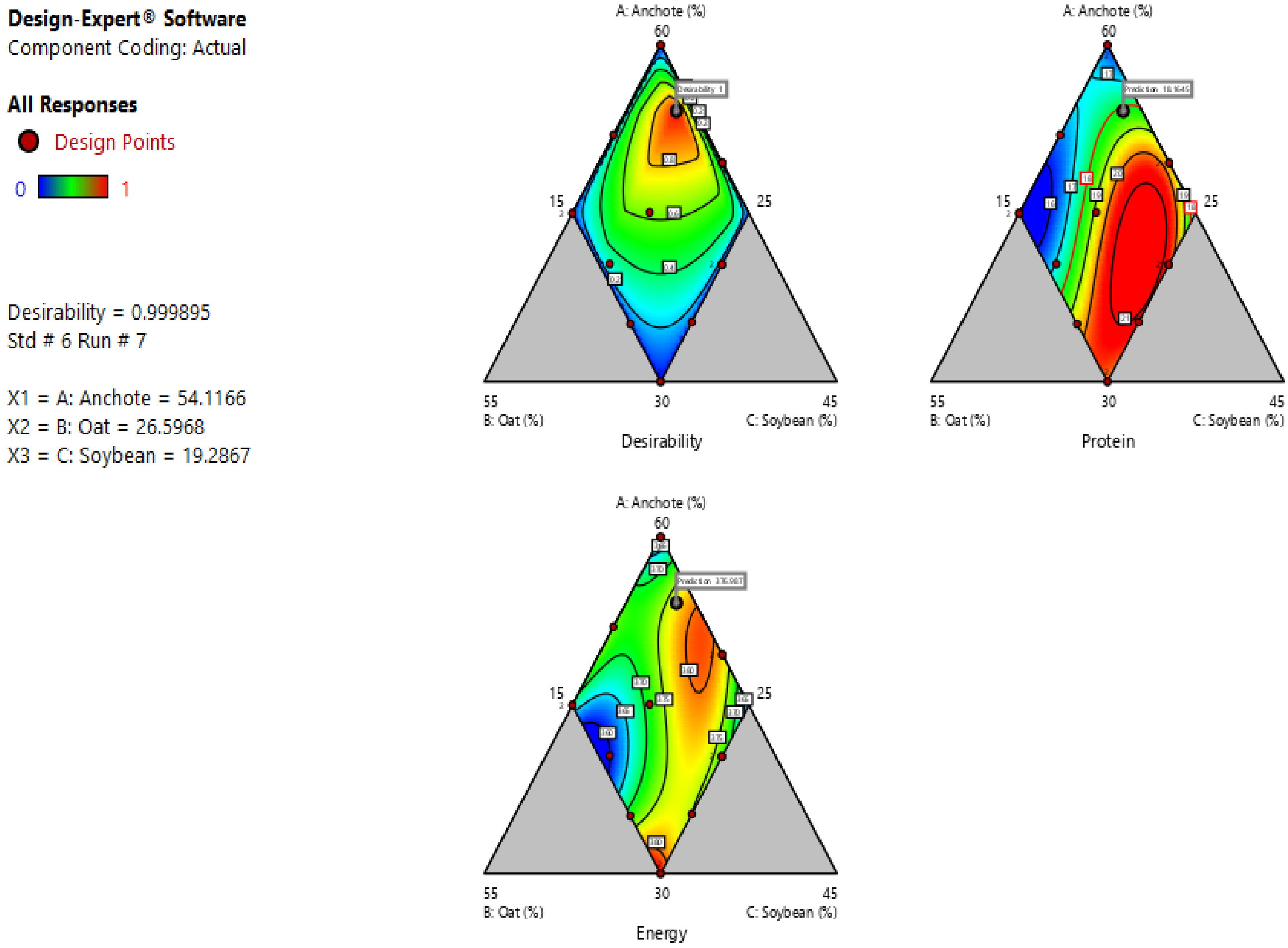


Figure.4.3 Desirability for all result

Protein

The prediction region for protein was stretch to formulations containing a high amount of anchote, (54.1%), small amount of soybean (19.28%) and moderate amount of oat (26.59%).

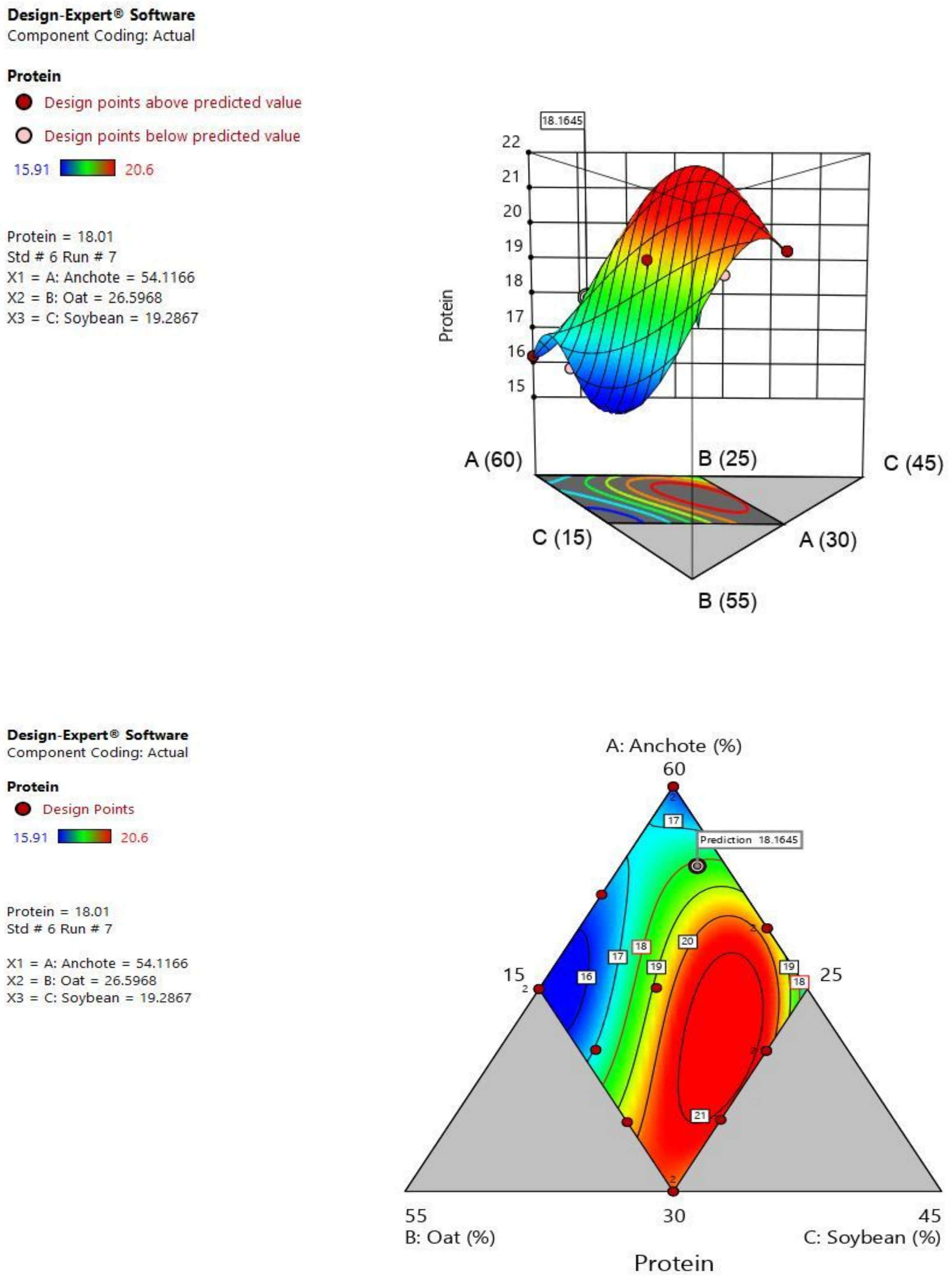
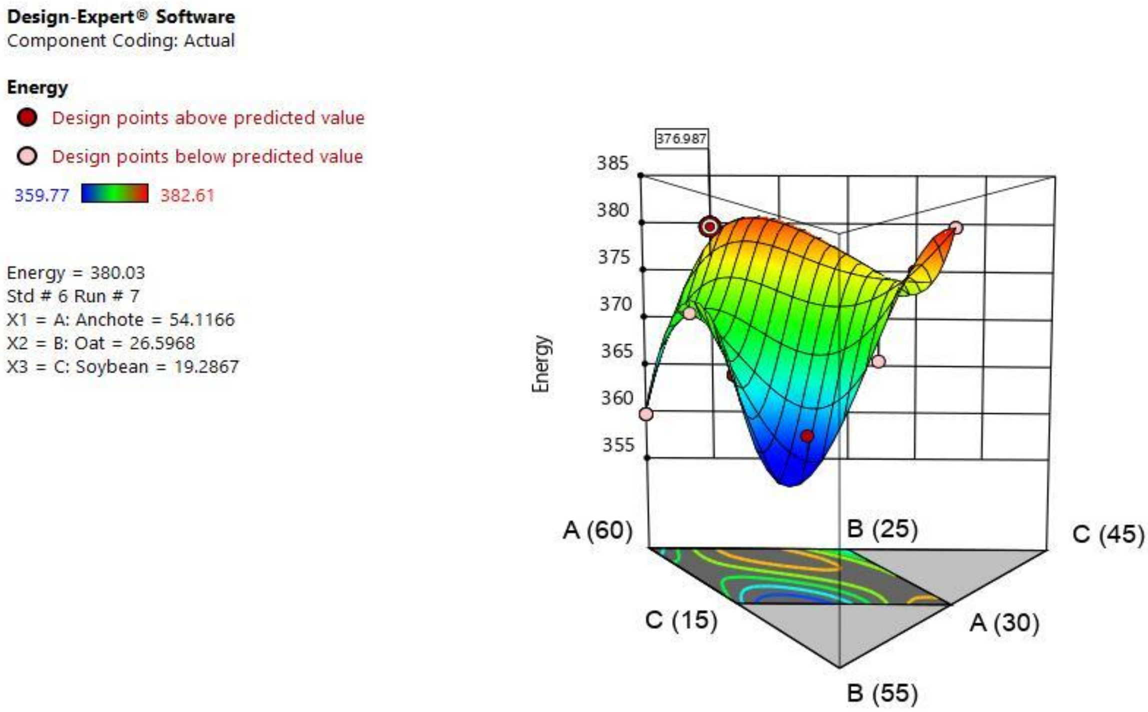


Fig 4.4 Protein plot (3D and counter)

Energy

The prediction region for energy was stretch to formulations containing a high amount of anchote, (54.1%) moderate amount oat (26.59%) and small amount of soybean (19.28%).



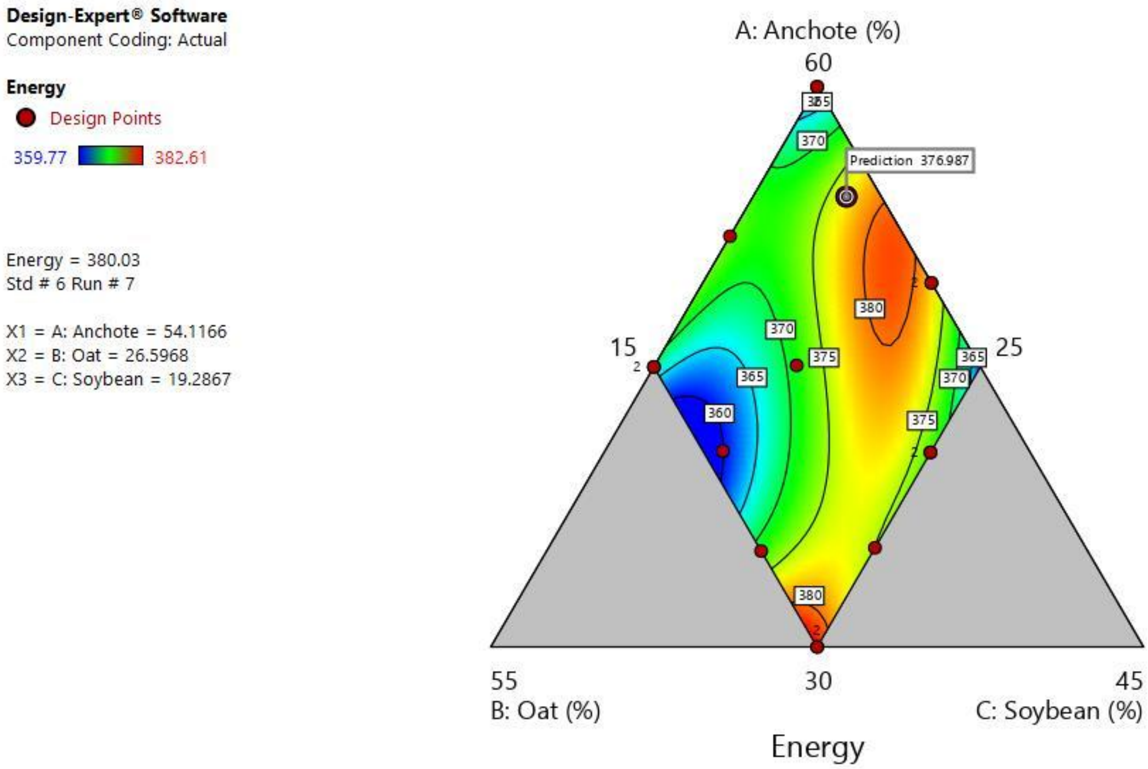


Fig. 4.5 Energy plot (counter and 3D)

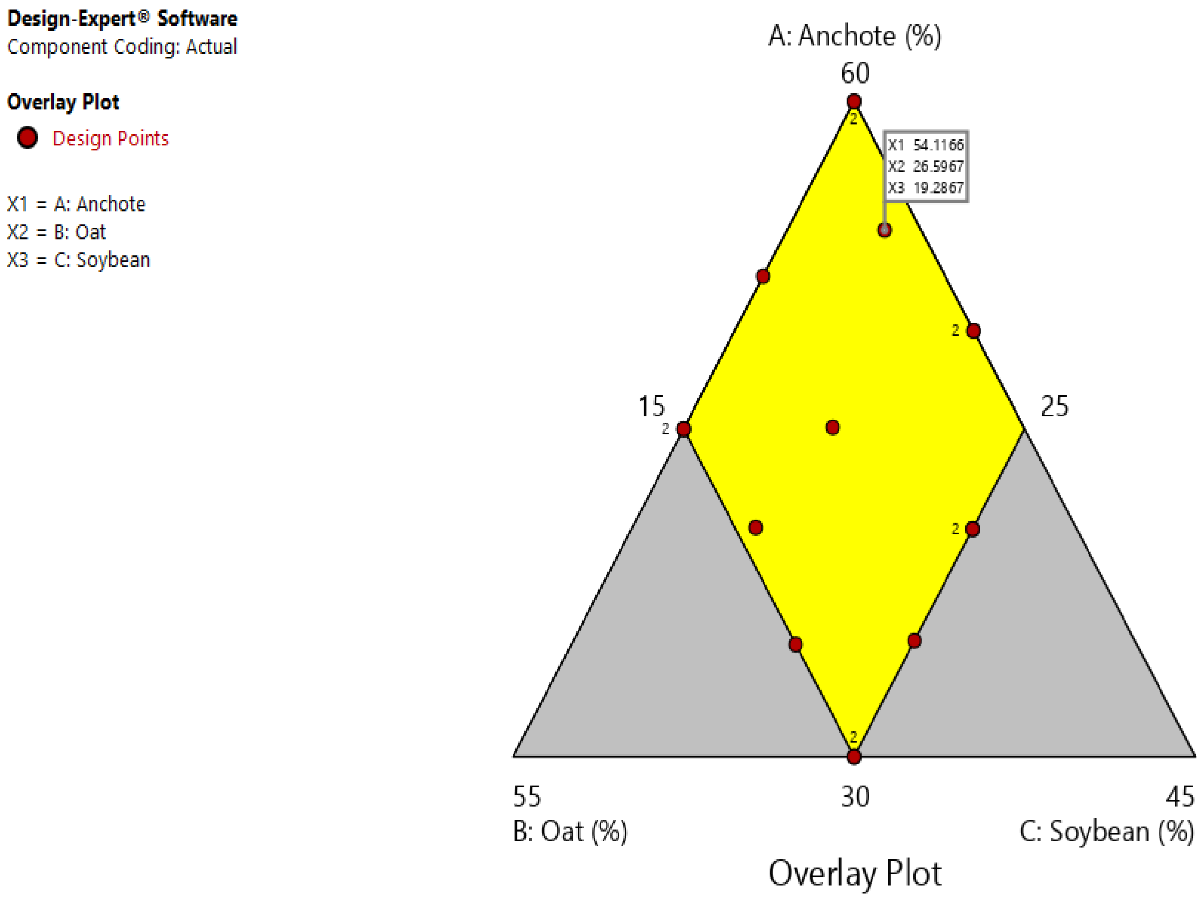


Fig. 4.6 Overlay counter plot

4.5 Chemical Composition of the Formulated Flour and Drum dried Baby Food Products.

- **Crude protein**

As it is shown in the Table 4.4, the mixture of Anchote, Oat and Soybean flour after drum drying contains a better content of crude protein (18.68%) than that of the formulated flour before drum drying (18.03 %). This showed that there was significant different ($P < 0.05$) between formulated raw flour and drum dried complementary food products and at high drum temperature with short contact time improves protein availability of the products and the denature of ant nutritional factors like phytate and tannins by heat may increase bioavailability of protein. Protein content of the drum dried anchote based developed baby food (18.68%) product was significantly higher than the commercial cerefam complementary food (14%). It was able to meet the protein standard of CAC (2011) standards. Adenuga (2010), however, reported relatively higher protein content (14 - 40%).

This may have been due to the high protein contents of anchote, oat and the level of soybean in this formulation of complementary food. Although drum drying process reduces some amino acids such as isoleucine and methionine, lysine content is significantly increased. The drum temperature had significant effect ($P < 0.05$) on the protein content of drum dried complementary food products. This is due to the fact nutritive value of a protein depends on the relative amounts of the essential amino acids, the proteins digestibility and bioavailability (Mensa-Wilmot *et al.,* 2001). Proteins undergo cross-linking reactions due to the applied heat and shear that causes denaturation of the proteins during drum dryer processing. The cross-linking causes the formation of a new molecular aggregate structure (Cindio *et al.,* 2002b).

There was significant different ($P < 0.05$) among the drum dried complementary food products that dried at different drum drying conditions. As a result, the possible cause might be the denaturation of proteins and inactivation of anti-nutritional factors that impair digestibility. Generally the value of protein that is obtained before and after drum dryer processing are 18.03% and 18.68% respectively. This protein result is within the range of infant food cerifam and (famix) (≥ 14%), product of Faffa Food S.C; higher than the minimum protein requirement (14%) of WFP specification for corn-soya blend and within the range to the values (16.00% – 19.97%) reported by the authors Lalude *et al*. (2006) of a weaning food from Sorghum and Oil - Seeds; Codex/WHO/FAO 2004 the required daily recommended protein in the complimentary food are ≥15%. Finally suggest that increasing of the protein can improve the protein content of complimentary food (Barac *et. al* 2010).

- **Total carbohydrates**

Generally complementary food products had the highest total carbohydrate content than the Formulated raw flour. As it was showed from the table 4.4, the carbohydrates content of formulated raw flour and developed anchote based ready to eat complementary food product were 63.17 and 66.42, 67.29, 68.39, 68.94, 69.22, 70.56, 70.91, 71.18% respectively. The cause of the higher carbohydrate content of the drum dried product might be due to starch degradation in to dextrin and simple sugars like free glucose, this is easily observed in increasing the WSI values of the product. All experimental values of carbohydrates before and after drum dry processing is comparable with Values (63.14% and 71.18%) respectively. Carbohydrate contributes a lot towards energy in complementary foods. Its content could be high but must be digestible enough for infants and young children to obtain the energy required or needed CAC (2011).

There was significant difference ($P < 0.05$) between carbohydrate content of drum dried anchote based developed complementary food product (71.18%) and the commercial cerifam complementary food (74%). The carbohydret content of drum dried complementary food product was higher than famix (70%) product of Faffa food S.C. Carbohydrate content of the developed anchote based complementary foods were able to meet FAO (1990), and CAC (2011) standards for carbohydrate. The carbohydrate content of the developed product was also higher than the reported by Bonsi *et al.* (2014) and Haque *et al.* (2013) (42.30–54.5%).

Research findings for carbohydrate contents of complementary food by Mbata *et al*. (2009) for fermented maize flour and Bambara groundnut-maize fortified flour; slightly higher than the values obtained from Famix (infant foods) – (70%) and slightly lower than (Shimelis, 2009) with the average value of (75%) for the production of sorghum based weaning food; higher than the values (60.85 and 61.99) reported by the authors Amankwah *et al.* (2009) for different blend ratio in the formulation of weaning food from fermented maize, rice, soybean and fishmeal. Bolaji *et al.* (2010) reported that the total carbohydrate content of maize – soybean blend for the production of Ogi is (61.76%). That is lower than the value of the Research finding. WHO/FAO (2004) recommended carbohydrate content of complementary food products are ≥65g/100g.

- **Crude fat**

As it is shown in the table 4.4, the crud fat content of drum dried complementary food product & formulated raw flour were 3.68 % and 5.65 % respectively. The drum dried Complementary food products had the lowest crude fat content than the formulated raw flour. This is possibly due to loss of some free oil at the drum dryer processing. The drum drying temperature had significant effect ($P < 0.05$) on fat content of drum dried complementary food products. Research finding values of crude fat content before and after drum dryer processing values of complementary food products were 5.65% and 3.68% respectively and there was significant different ($P < 0.05$) among the drum dried complementary food products. This result was due to the different level of drum dryer temperature, drum speed and the loss of free oil from the product due to high temperature. The fat content of the developed anchote based ready to eat baby food was significantly higher (5.35%) than the commercial cerifam complementary food (4%) but lower than famix (10.46%).

Statistically a significant difference (P < 0.05) was observed between developed drum dried product and cerifam complementary food and famix. The higher fat content in anchote based ready to eat complementary food product could be attributed to the composition of the product and the product is often made with soybean and oat. Oat and soybeans contributed to the high fat content.

WHO/FAO recommended crude fat content of complimentary food products are 10-15%. Although the developed anchote based ready to eat baby food product was unable to meet these standards, but it was higher than complementary food products reported by Adenuga (2010) (2.40–2.80%) and Bonsi *et al.* (2014) (4.30%). Lalude & Fashakin (2006) reported that the fat content of weaning food from sorghum and oil – seeds is (9.87%). According to the findings of Amankwah *et al*. (2009), the crude fat content of formulation of weaning food from Fermented maize, rice, soybean and fishmeal is (9.38% and 8.75%). The lower fat content had contributed to lower energy value of the prepared weaning food. The lower fat content may also have contributed to the increase in the shelf - life of the formulation by decreasing the chances of rancidity (Onuorach and Akijede, 2004).

❖ **Moisture**

The results moisture content was presented in table 4.4. The moisture content of formulated raw flour was (5.27%) and the drum dried complementary food products were ranges from (1.73% to 2.83%). Those values are in agreement with the values obtained from (Shimelis, 2009). Such low moisture content of flours prevents microbial activity and extends the shelf life of the flour (Kikafunda, 2006). Amankwah *et al*. (2009) reported that the removal of moisture generally increases concentrations of nutrients and can make some nutrients more available.

Drum temperature had significant effect (P < 0.05) among the moisture content of the drum dried complementary food products. As drum temperature increased and drum speed decreases, the moisture content of food products decrease from the value of 5.27%, to 1.73%, this is possibly due to loss of some free water at the drum dryer surface. The drum speed with drying temperature had significant effect (P < 0.05) on the moisture content of drum dried complementary food products, this may due to the more exposure of product to the drum temperature with slow drum speed, highly decreases moisture contents of the product.

As the drum speed decreases, the more exposure of the product to drum temperature that remove more water from the dried products and this showed that the temperature, drum speed and moisture content had inversely relationship to each other.

Table 4.4: Chemical composition of the formulated flour and complementary food products.

Sample code	Drum Temp (°C)	Drum speed (rpm)	Particle size (mm)	Moisture%	Protein%	Fat%	Ash%	Fiber %	CHO(%)	Energy (Kcal)
Formulated. flour	_	_	_	5.01±0.330^{a}	18.01±0.07^{ab}	5.99±0.69^{a}	3.5±0.28^{ab}	5.18±0.16^{c}	63.52±0.417^{e}	380.03±1.40^{e}
Pr1	160	300	0.6	2.26±0.35^{bc}	16.67±0.17^{c}	4.63±0.01^{ab}	3.33±0.2^{ab}	2.09±0.09^{b}	70.91±0.156^{a}	394.50±0.35^{bc}
Pr2	160	300	0.8	2.02±0.148^{c}	17.45±0.07^{bc}	3.70±0.98^{b}	5.46±0.42^{b}	2.83±0.035^{ab}	70.56±0.410^{a}	397.16±1.6^{ab}
Pr3	145	200	0.6	2.83±0.56^{bc}	18.68±0.14^{a}	5.30±0.27^{a}	4.27±0.27^{a}	3.29±0.014^{ab}	68.94±0.212^{b}	399.82±0.87^{a}
Pr4	145	200	0.8	3.52±0.74^{b}	18.4±0.30^{ab}	5.3±0.113^{ab}	3.97±0.42^{ab}	3.64±0.35^{a}	67.29±0.24^{cd}	392.3±1.03^{cd}
Pr5	145	300	0.6	2.52±0.18^{bc}	18.38±0.18^{ab}	4.79±0.30^{ab}	4.04±0.28^{ab}	2.84±0.52^{ab}	68.39±0.14^{bc}	392.06±0.87^{cd}
Pr6	145	300	0.8	2.52±0.13^{bc}	17.42±0.14^{bc}	3.68±0.32^{b}	3.73±0.43^{ab}	3.19±0.46^{ab}	71.18±0.919^{a}	388.6±1.32^{d}
Pr7	160	200	0.6	2.08±0.17^{bc}	17.50±0.04^{bc}	4.88±1.18^{ab}	4.07±0.57^{b}	2.07±0.14^{b}	66.42±0.679^{d}	382.58±0.67^{e}
Pr8	160	200	0.8	1.73±0.129^{c}	16.49±0.66^{c}	4.16±0.12^{ab}	4.47±0.42^{ab}	2.31±0.41^{b}	69.22±0.134^{b}	384.07±0.88^{e}

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p>0.05$)
All values are means of triplicate ± standard deviation

❖ Fiber content

The results of fiber content of formulated raw flour and the developed drum dried complementary food products were displayed in table 4.4. Fiber containing food is better for maintaining good health but, infants do not get benefit from a high fiber intake and therefore fiber levels must be controlled in children's foods. In this study, the fiber content of formulated baby food was 5.18% and the developed drum dried baby food contains ranges from 2.07 to 3.64 %.

The fibre content of the developed anchote based complementary foods was low (2.07%) and meets the criteria set by CAC/GL 08 (1999) and CAC (2011); which reports that fibre content should be less than 5%. This is because the presence of high quantities of fibre makes the food bulky and induces flatulence which is an uncomfortable feeling in infants (Codex alimentareous Commission, 2011). Moreover, digestion of high fibre foods is a difficult task for infants, since their digestive system is not well developed at that stage. The fibre contents the developed baby food product was lower than what was reported by Adenuga (2010). Fiber is an important dietary component in preventing overweight, constipation, cardiovascular disease, and diabetes and colon cancer. However, high dietary fiber content has been reported to impair protein and mineral digestion and absorption in human subjects.

- **Ash content**

The ash contents of raw formulated flour was 4.26% and the drum dried complementary food products were ranges from 3.33, 3.97, 4.04, 4.07 4.27, 4.47, 5.33 and 5.46% respectively. Significant difference ($P < 0.05$) were observed between the ash contents of the developed anchote based ready to eat baby food products. Drum temperature had significant effect ($P < 0.05$) on ash content of drum dried complementary food products and the highest value of ash content occurred at high temperature of drum dryer with high drum speed. This result may showed that the high temperature of the drum increases, the more bioavailability of minerals for drum dried complementary food products.

The presence of ash is an indication of minerals present in the sample (Owiredu, Laryea, & Barimah, 2013). The ash is relatively higher than what was reported by Bonsi, Plahar, and Zabawa (2014) (1.39–1.98%) and Haque *et al*., (2013) (1.90–2.14%) in their OFSP complementary foods. However, Adenuga (2010) and Amagloh *et al*., (2012) had also relatively lower ash content, 2.80–11.25%, in their sweet potato-based complementary foods developed. FAO (1990) reported that the ash content of a complementary food should be less than 5%. The drum dried complementary food product, therefore, slightly meets this standard.

- **Energy**

The calories of infant's diet are provided by protein, fat and carbohydrates (Amankwah *et al.,* 2009). As it is shown in the table 4.4, the calorific value of the formulated flour was 380.11kcal and that of drum dried products ranges from 382.58 to 399.8 kcal. The energy value of anchote based ready to eat complementary food product was significantly higher than commercial cerifam complementary food (396 kcal) product of Faffa food S.C.

Accordingly to previous researchers (Griffith et al., 1998) of weaning food; higher than the value (398.9 kcal.) and "Nutrend" (Nestle, Nigeria-weaning diet) obtained commercially and lower than the experimental value (441 kcal.) obtained from the author Lalude & Fashakin, (2006). The value is also in the range with WHP specification minimum requirement of (380kcal.) for the weaning food from corn-soya blend (CSB) and as reported from Onilude, (1999), they are slightly lower than the values of unfermented blend (418.0kcal.) and fermented ones (464.2kcal.) for the composite blend of cereal and soybean for infant food.

4.6 Effect of Drying Operating Variables on Physical Properties of Products

4.6.1 Viscosity

The viscosity result of the developed complementary food products were presented in the table 4.5. The viscosity of raw formulated flour was 6.29Mpa and drum dried complementary food products were 3.07, 3.29, 3.44, 3.45, 3.9, 4.05, and 4.34 to 4.47Mpa respectively. There was significant different ($P < 0.05$) between raw formulated flour and drum dried complementary food products. This result showed that drum drying process decreases the viscosity of the developed complementary food products. Temperature had significant effect ($P < 0.05$) on the viscosity of complementary food products. As it was showed in the table 4.7, as temperature increases from 145^{o}C to 160^{o}C the viscosity of the complementary food product decrease from 4.47Mpa to 3.07Mpa respectively. The decrease in viscosity of the product happen due to increase in temperature that makes the product particles move faster and begin to move away from each other. Because, the particles are moving around more, they can flow more and hence their viscosity is lower. This result showed that drum drying temperature had significant effect ($P < 0.05$) on viscosity of the developed complementary food products.

Furthermore, Particle size distribution of the product affect the viscosity of complementary food product. Particle size increase from (0.6mm to 0.8mm) the viscosity of the product decrease from 4.47MPa.s, to 3.07MPa.s respectively. Due to this size of the particles of a substance, the viscosity of the product greatly affected. The number of particles were increase when particle size decreases. As a result of this, the number of interactions between particles decreases as well, leading to an overall decrease in viscosity.

4.6.2 Bulk density

As it is shown in the table 4.5, the bulk density of formulated raw flour is 0.66g/ml and that of the drum dried products were ranges from (0.52 to 0.62g/ml). The temperature had significantly affect the bulk density of complementary food products. As it is shown in the table 4.5, the temperature increase from (145^{o}c to 160^{o}c) bulk density of the product decrease from (0.62 to 0.52 g/ml). This is due to density decreases with increase temperature and due to starch gelatinization. Lower bulk density is best for a complementary food (Akubor *et al.,* 2013). Higher bulk density implies lesser spaces between particles of flours. This will end up increasing the viscosity of the flour. For complementary foods, high viscosities are not desired because consumption and digestion becomes difficult for babies.

This will result in the addition of more water by most mothers, hence reducing the nutrients of the food per serving to a baby. Increased gelatinization increases volume of products consequently bulk density decreases. At high temperature the gelatinization of the starch is more complete. The bulk densities of anchote-based complementary food were found to be lower than that reported by (Ikujenlola *et al.*, 2014) but comparable to complementary food developed by Ayo-Omogie and Ogunsakin, 2013. The various components used in the formulation of the complementary foods were different.

Significant differences ($p < 0.05$) were observed among drum dried complementary food products. Furthermore, Particle size affect bulk density of the product. As the particle size increased from (0.6mm to 0.8mm) the bulk density of food product decreased from (0.62g/ml to 0.52g/ml) respectively. This may due to the increase in number of particles when particle size decreases. The values of the current study disagree with range value (0.657 and 0.605) reported by Lalude & Fashakin (2006) of a Weaning Food from Sorghum and Oil – Seeds and Nutrend – Nigerian commercial weaning food respectively.

Table 4.5: Effects of drying variables of the drum dryer on physicochemical properties of the product.

Sample Code	Drying Parameter	Bulk density(g/mL)	Water activity	PH value	Viscosity(MPas)
Rff	Form flour	0.660 ± 0.0255^{a}	0.3815 ± 0.020^{a}	5.985 ± 0.0495^{a}	6.290 ± 1.259^{a}
Pr1	160,300,0.6	0.545 ± 0.022^{bc}	0.2395 ± 0.0177^{b}	6.335 ± 0.163^{a}	3.450 ± 0.750^{b}
Pr2	160,300,0.8	0.577 ± 0.027^{abc}	0.2415 ± 0.0233^{b}	6.06 ± 0.141^{a}	3.97 ± 1.43^{b}
Pr3	145,200,0.6	0.595 ± 0.021^{abc}	0.2795 ± 0.0474^{ab}	6.090 ± 0.15^{a}	4.050 ± 0.877^{ab}
Pr4	145,200,0.8	0.609 ± 0.029^{abc}	0.2640 ± 0.0410^{ab}	5.980 ± 0.056^{a}	3.445 ± 0.686^{b}
Pr5	145,300,0.6	0.617 ± 0.017^{abc}	0.2935 ± 0.0488^{ab}	6.110 ± 0.127^{a}	4.340 ± 0.877^{ab}
Pr6	145,300,0.8	0.627 ± 0.029^{ab}	0.3025 ± 0.0361^{ab}	6.340 ± 0.084^{a}	4.475 ± 0.728^{ab}
Pr7	160,200,0.6	0.525 ± 0.028^{c}	0.213 ± 0.0276^{b}	6.230 ± 0.014^{a}	3.075 ± 1.237^{b}
Pr8	160,200,0.8	0.527 ± 0.024^{c}	0.220 ± 0.0311^{ab}	6.12 ± 0.198^{a}	3.290 ± 0.651^{b}

$^{a-c}$ Means with the same superscript letters within a column are not significantly different ($p > 0.05$)

All values are means of triplicate ± standard deviation

4.6.3 pH value

The result of pH values of the raw formulated flour and drum dried complementary food products were 5.985 and 6.34. From the result we observed that there was no significant ($P > 0.05$) different between the pH value of the raw formulated flour and the drum dried complementary food product. Drum drying process and particle size distribution of the product had no significant effect ($P > 0.05$) on the pH values of the drum dried complementary food products and there is no significant different ($P > 0.05$) between all the product with different drum drying conditions and particle size of the products. This shows that there is no acid production during drum drying of the product and this does not lowers the pH value of the products.

4.6.4. Water activity

The results for the water activity of the formulated flour and drum dried anchote based complementary food products are displayed in table 4.5. The water activity of formulated raw flour was 0.38 and that of the drum dried complementary food products were ranges from 0.21 to 0.30. This shows that there was a significant ($P < 0.05$) different between the water activity of raw formulated flour and drum dried complementary food products. All the drum drying process had a significant effect ($P < 0.05$) on the water activity of the drum dried complementary food products. There was a decrease of water activity of the products with increased drum temperature and reduced particle size of the product.

There was Significant different ($P < 0.05$) among the drum dried complementary food product developed and the lowest value of water activity (0.21) was recorded for product Pr7 that was dried at drum temperature of 160^{o}C, drum speed of 200rpm and with particle size of 0.6mm. The highest value of water activity was observed for product Pr6 that contains 0.30 and this product was dried at drum temperature of 145^{o}C, drum speed of 300rpm and particle size of 0.8mm. From this result observed that as drum dryer temperature increased and particle size decreases, the water activity of the drum dried products were reduced. The drum temperature and particle size had significant effect ($p < 0.05$) on the water activity of developed complementary food products and this shows that drum drying process improves shelf life stability of product and reduce the growth of microbes in the products.

4.7 Functional Property of the Formulated Flour and Dried Product

WAC, an indicator of the ability of flour to absorb water, depends on the availability of hydrophilic groups which bind water molecules and on the gel-forming capacity of macromolecules. WAC is the measure of the swelling power of the starch (Kite *et al.*, 1957: Anderson et al., 1996). Water Absorption capacity (WAC) characterized how the products will interact with water and are often important in predicting how the formulated complementary food products may behave if further processed. Also the degree of conversion of starch from granule during processing can be accessed via WAC (seriburi *et al*., 1999).

Table 4.6: Effect of drying parameter of drum dryer on formulated complementary food products.

Sample code	Drying parameter	WAC(mL/g)	OAC(mL/g)	Dispersibility (%)	Swelling power(g/g)	Solubility index (%)
Rff	Formted flour	1.260±0.0283[d]	1.4200±0.0283[ab]	50.50±2.12[c]	2.680±0.0141[b]	41.23±4.24[c]
Pr1	160,300,0.6	2.560±0.0424[abc]	1.4850±0.0212[a]	65.77±3.15[a]	3.750±0.35[ab]	56.50 ± 2.12[ab]
Pr2	160,300,0.8	2.455±0.0495[bc]	1.3250±0.035[bcd]	61.725±1.025[ab]	3.48±0.728[ab]	56.91±4.12[ab]
Pr3	145,200,0.6	2.670±0.0424[a]	1.370±0.0284[abc]	57.84±3.06[abc]	2.72±0.523[ab]	54.05±3.32[abc]
Pr4	145,200,0.8	2.570±0.0424[ab]	1.360±0.0424[bc]	52.25±3.18b[c]	2.99±0.177[ab]	49.47±4.45[abc]
Pr5	145,300,0.6	2.395±0.0354[c]	1.275±0.0354[cd]	61.25±3.33[abc]	3.10±0.424[ab]	58.0±4.24[ab]
Pr6	145,300,0.8	2.530±0.0424[abc]	1.230±0.0283[d]	57.855±1.209[abc]	3.02±0.389[ab]	46.37±3.35[bc]
Pr7	160,200,0.6	2.750±0.0424[a]	1.255±0.0354[d]	65.50±3.54[a]	4.170±0.467[a]	63.20±3.39[a]
Pr8	160,200,0.8	2.650±0.0566[a]	1.240±0.0141[d]	59.95±2.76[abc]	4.085±0.771[a]	50.85±3.61[abc]
Control	Cerefam	4.27±0.615[f]	2.432±1.179[e]	79.65±3.04[d]	6.345±0.629[d]	69.38±4.83[e]

[a-f] Means with the same superscript letters within a column are not significantly different ($p>0.05$)

All values are means of triplicate ± standard deviation

4.7.1 Water absorption capacity

The Water Absorption Capacity (WAC) of a food product is its ability to absorb moisture. It is defined as the amount of moisture taken up by the flour to achieve a desired consistency or optimal result. The WAC of the drum dried complementary food products were in range of 2.39 to 2.67ml/g. WAC was highest in Pr3 and least in Pr5 (Table 4.6). The WAC of the formulated raw flour, commercial complementary food (cerefam) were 1.26g/ml and 4.27 respectively. The drum dried complementary food product has the highest WAC than that of the formulated raw flour and lower than commercial complementary food (cerefam). This is possible due to Protein denaturation, more starch gelatinization and, swelling of crude fiber, which occur during drum dry processing and the different type of ingredients between the developed product and that of the commercial complementary food.

Drum drying process had significant effect ($P < 0.05$) on water absorption capacity of drum dried complementary food and as observed from the table 4.6 results, as the drum drying temperature increases and drum speed decreases, the water absorption capacity (WAC) of the drum dried complementary food products increases. A flour or starch sample with higher water absorption capacity at low temperature is a suitable ingredient for quick preparations or instant food (Pacheco-Delahaye, E and Maldonado, 2008). This may happen when there is a full or complete gelatinization of the starch granules.

As it was observed from the table 4.6, the temperature affect WAC of the complementary food products. As drying temperature increased from 145^{o}C to 160^{o}C, WAC of the product increased from 2.39 to 2.67ml/g respectively. This is due to starch gelatinization and swelling of crude fiber, which occur during drum drying process. Drum dry process could be responsible for the increasing water absorption capacity (WAC) value of products. A flour or starch sample with higher water absorption capacity at low temperature is a suitable ingredient for quick preparations or instant food (Brou *et al.* (2013). Particle size had significant effect ($P < 0.05$) on water absorption capacity of the products. As it was shown from the table 4.6, as the particle size increase from 0.6mm to 0.8mm the WAC value of drum dried complementary food decreases from 2.67 to 2.39ml/g respectively.

This might have been caused probably a more open structure was formed during drum drying process with small particle size which could allow water penetration and retention in the product. Edema *et al.* (2005) reported that the water absorption of flour from commercially sold flour maize and Maize-soy flour blend is (1.94% & 1.72% respectively). This result indicated that the water absorption blend flour is lower than that of the researches findings. Olapade *et al*. (2015) reported a much higher water absorption capacity (150-180%) in plantain and cowpea complementary blends. Brou *et al*. (2014), using maize, millet, beans and soybeans in the development of complementary foods also reported a range of 95 to 133%.

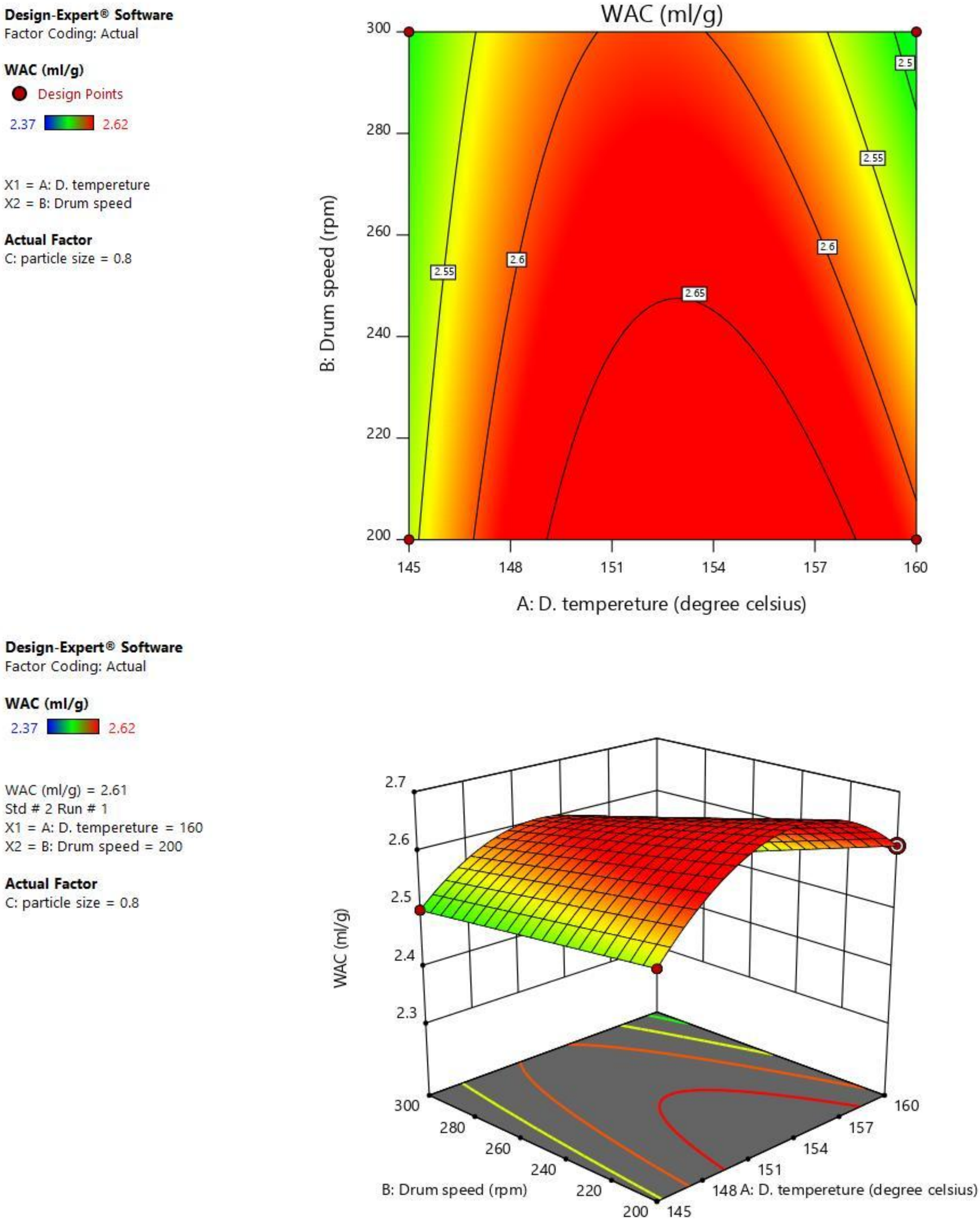


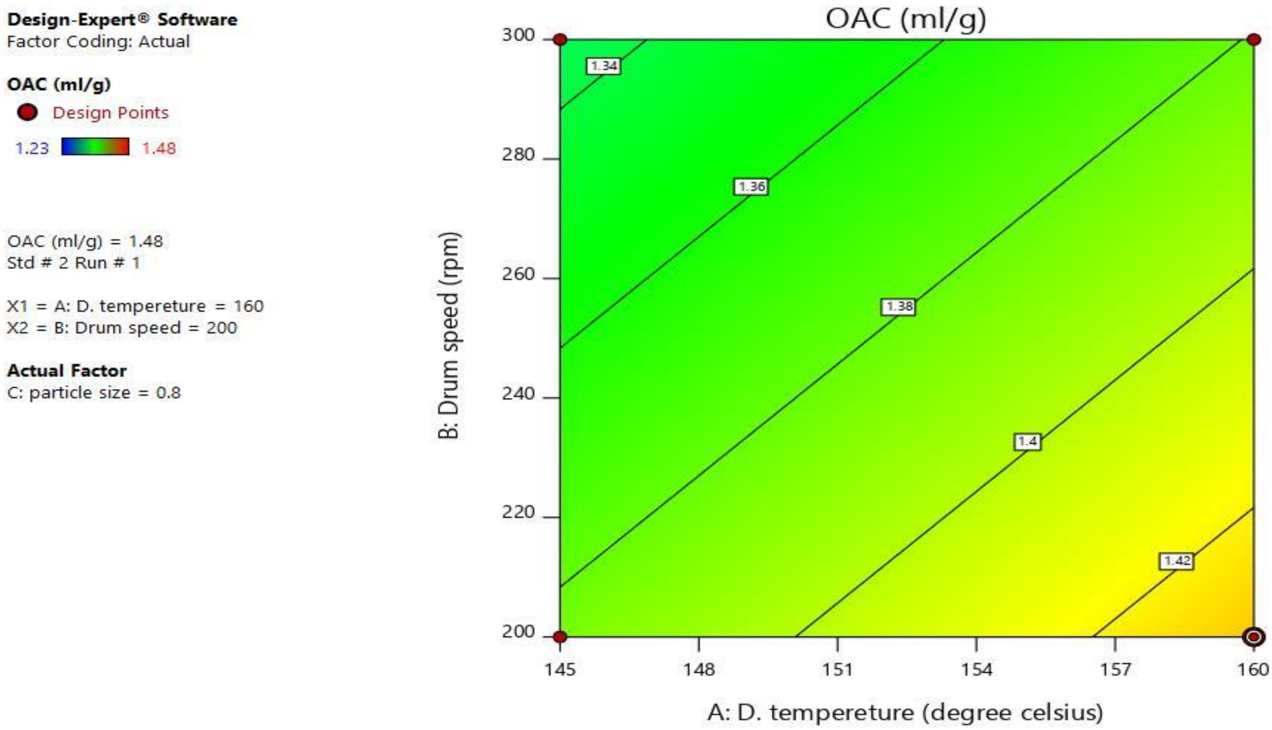
Figure 4.7 Contour and 3D representation of WAC

4.7.2 Oil absorption capacity

The results for oil absorption capacity was given in Table 4.6.The oil absorption capacity of raw formulated flour was 1.42ml/g and the drum dried complementary food was ranges from 1.23 to 1.48ml/g with particle size distribution from 0.6 to 0.8mm. There was significant different ($P < 0.05$) between formulated raw flour and drum dried complementary food products. This result indicates that the oil absorption of developed complementary food product was higher than that of formulated raw flour. This result indicates that the oil absorption capacity of product is higher than that of formulated raw flour. This due to the ability of flour to retain flavor and improved mouth feel during drum dry processing. But commercial complementary food (Cerefam) has higher OAC (2.43ml/g) than that of the developed anchote based complementary food products. This may be due to the deferent in raw materials type and the different in their chemical properties. The commercial complementary food products made from wheat, soybean and milk powder. But the developed complementary food products made from anchote (ground tuber), Oat and soybean. So, all these ingredients were different in their characteristics.

Drum drying temperature had significant effect ($P < 0.05$) on drum dried complementary food products and this result showed that the drum drying temperature and particle size affect the oil absorption capacity of the developed complementary food products. The product that dried at drum temperature of 160^{o}C with particle size of 0.6mm contains higher oil absorption capacity (1.48ml/g) than that of the product dried at drum temperature of 145^{o}C. Particle size significantly affect ($P < 0.05$) oil absorption capacity of the product. As it was shown from table 4.6, particle size increase from (0.6mm to 8mm), oil absorption capacity value decreases ranges from (1.48, 1.37, 1.36, 1.32, 1.27, 1.25, 1.24 and 1.23ml/g) respectively.

This may due to increase in OAC observed might have been caused probably a more open structure was formed during drum dryer processing which could allow oil penetration and retention in the product (Artz *et al*., 1990). The values obtained from current study are lower than that of (1.22ml -2.23ml) reported by Fouzia (2009) of extrusion cooking of full-fat soy flour. Similarly, oil absorption of dried products were lower than the value (1.82ml, 1.44ml) for different varieties reported by Assefa (2008) of improved varieties of soybean in Ethiopia.



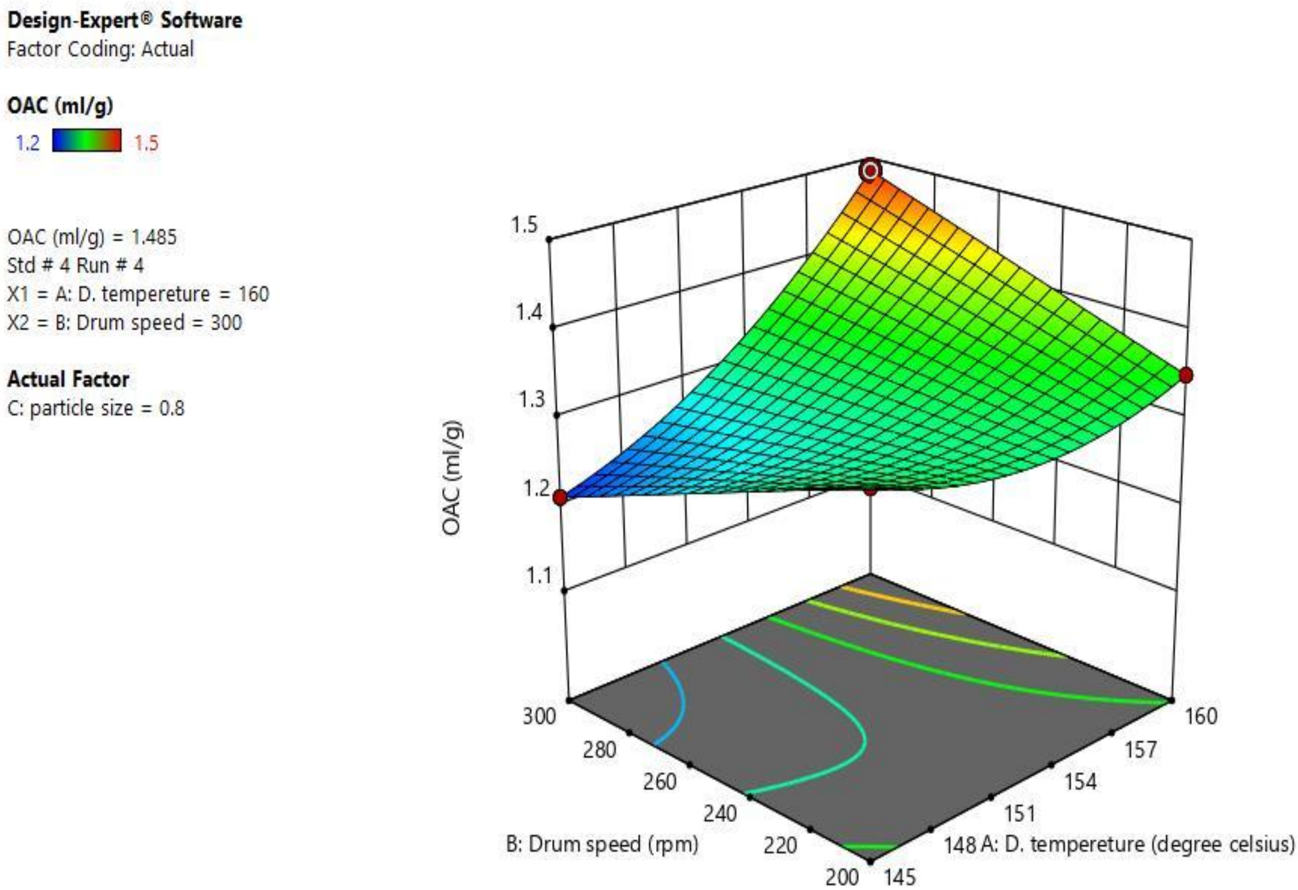
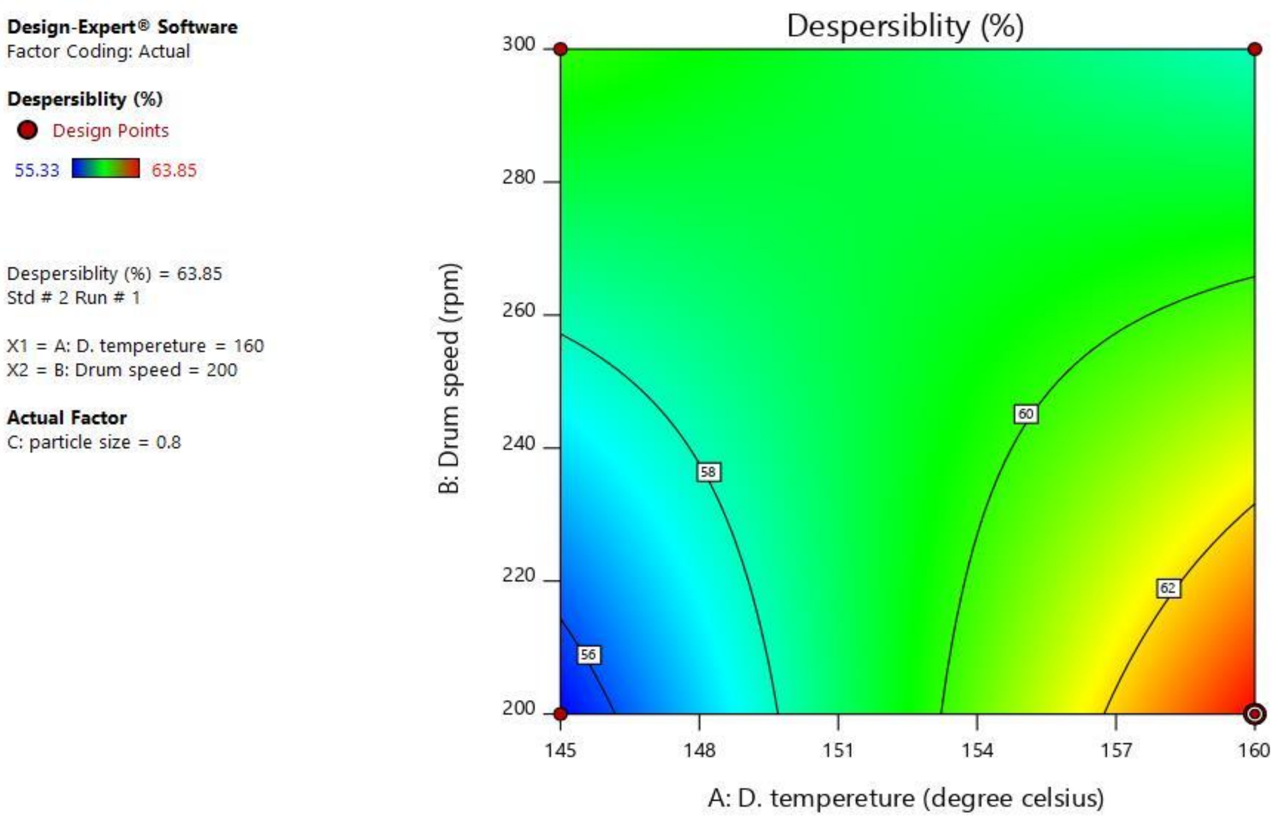


Figure 4.8 Contour and 3D representation of OAC

4.7.3 Dispersibility

The results for dispersibility was given in Table 4.6. The dispersiblity of the formulated raw flour and drum dried complementary food products were 50.5% and 65.77% respectively. There was significantly different ($P < 0.05$) between raw formulated flour and drum dried complementary food products and this result was occurred due to the effect of drum dry processing on the products. The dispersibility for drum dried products were within the range of 52.25 to 65.77% while formulated raw flour had a dispersibility value of 50.50%, which was significantly lower than that of the drum dried complementary food products. The commercial complementary food (Cerefam) has higher dispersiblity(79.65%) than the developed anchote based complementary food products(65.7%). There was a significant different ($P < 0.05$) between the developed complementary food products and the commercial complementary food (Cerefam). This result was occurred due to the effect of different drum dryer parameters and the different in processing conditions.

The drum dryer temperature and its' speed had significant effect ($P < 0.05$) on dispersiblity of the developed complementary food products and as temperature and speed of the drum dryer increases, despersiblity of the developed product increases and despersiblity of product decreases as temperature decreases. Particle size of the developed products had significant effect ($P < 0.05$) on despersiblity of developed complementary food products and as particle size decreases despersiblity of the product increases. The results obtained by Kulkarni *et al,* 2003 on diets formulated from green gram, sesame and sorghum malt flour ranged from 71% to 75% hence were higher than those of the developed complementary foods from 52.25 to 65.77%. The dispersibility of a diet in water indicates its reconstitutability. The higher the dispersibility value, the better the diet, hence the drum dried complementary food products diets were more suitable foods for infants due to its high dispersibility values.



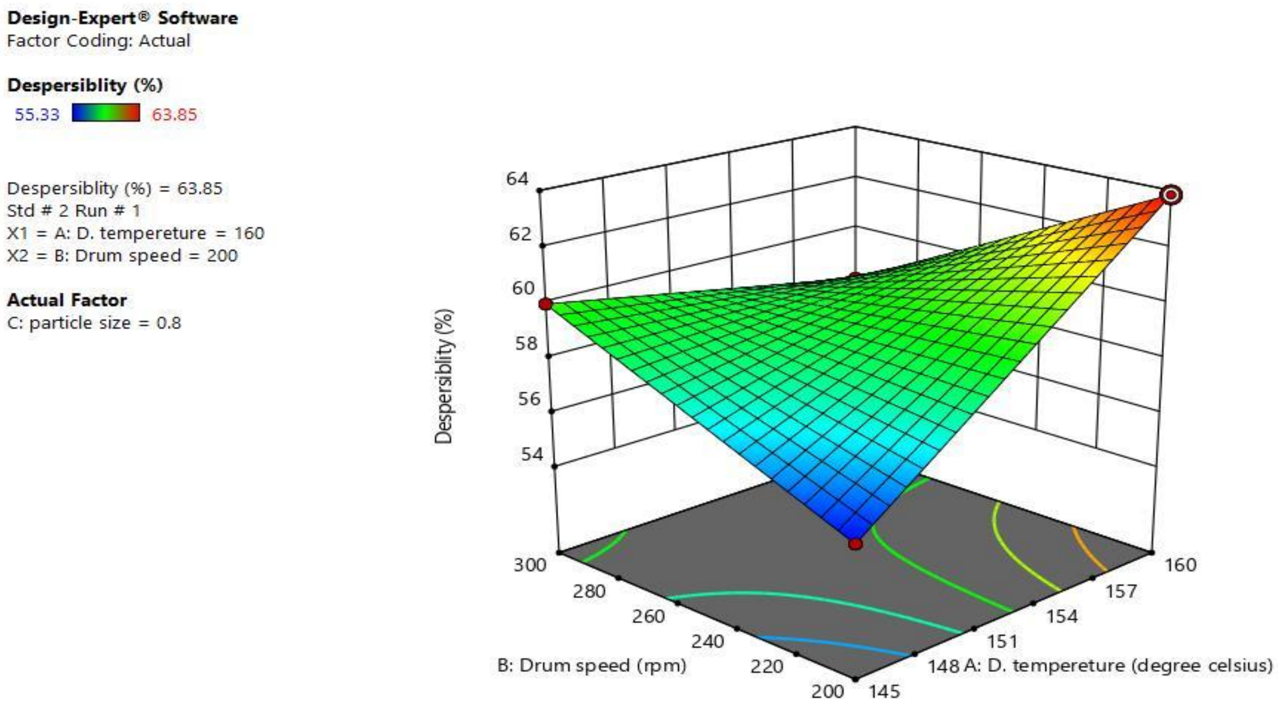


Figure 4.9 Contour and 3D representation of dispersiblity

4.7.4 Swelling capacity.

The swelling powers of the raw formulated flour and the drum dried product samples were 1.88g/g and 4.1g/g respectively. Swelling powers of the drum dried food product and raw formulated product samples were significantly ($P < 0.05$) different. Drum dried product had higher swelling power than the formulated raw flour; this may be attributed to the inhibitory action of lipid (fat) on water as Drum dried product had lower fat content than raw formulated flours presented in the table 4.6. Commercial complementary food (Cerefam) has higher (6.34g/g) swelling power than the developed anchote based complementary food products (4.17g/g). As swelling refers to absorption of water, it may be inhibited by the lipid content of the flour (Hood et al., 1998). The swelling power is an indication of presence of amylase which influences the quantity of amylose and amylopectin present in the product flour. The variation in the swelling power indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water (Ruales *et al*, 1993).

The swelling values showed a significant ($P < 0.05$) difference among the raw formulated flour and the drum dried product. This shows that drum drying process significant effect ($P < 0.05$) on the swelling capacity of the product. The highest swelling power (4.17g/g) was recorded for Pr7 that was dried at drum temperature of 160^{o}C, drum speed of 200rpm and particle size of 0.6mm and the minimum value was recorded for Pr3 (2.72ml/g) that dried at drum temperature of 145^{o}C, drum speed 200rpm and particle size of 0.6mm respectively. The drum temperature, drum speed and particle size had a significant effect ($P < 0.05$) on the swelling power of anchote based ready to eat baby food product developed at different drying conditions of the drum dryer with different particle size of the products. Drum drying of the product enhances the WAC of the flours and hence increases the swelling powers, as swelling power of starch-based flour is related to WAC of the flour during heating (Loos et al, 1981).

Complementary foods with high swelling power absorb more water and have less solids resulting in low nutrient density for the infant According to Nelson and Cox (2013), high swelling power is due to the water binding capacity of the legume protein. According to Majzoobi *et al*. (2008), drum drying is able to increase the cold water viscosity of flours while the native flours are unable to do the same. Therefore the anchote-based complementary food is able to form partial viscous solutions in cold water due to the process of drum drying; thereby making it instant food for infants. Moderate to high swelling power would enhance functionality of flours in foods such as baby foods and breakfast cereals.

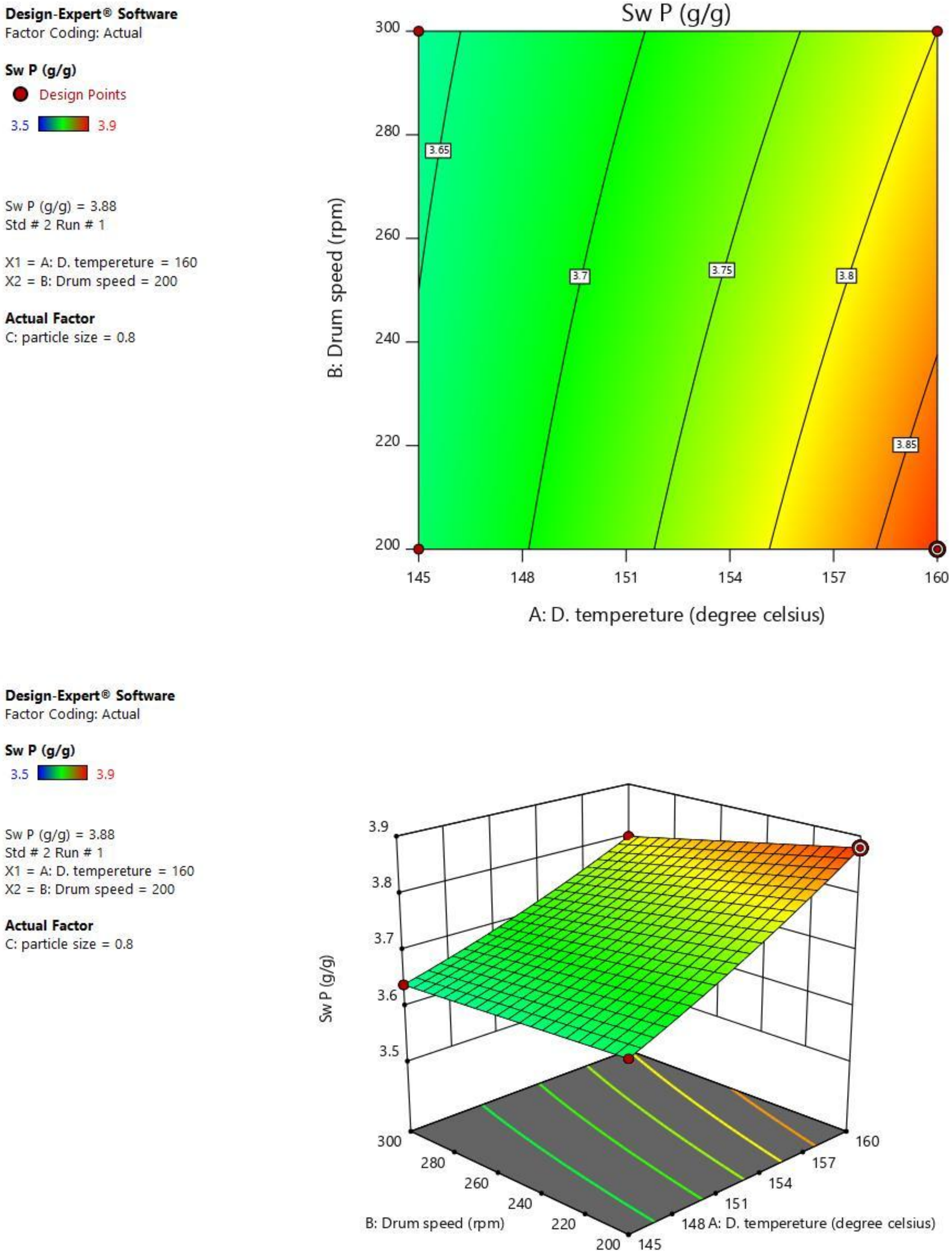


Figure 4.10 Contour and 3D representation of swelling capacity

4.7.5 4.7.5 Solubility power

The results of the solubility index for the raw formulated flour and developed complementary food product were displayed in table 4.6. From the table it was observed that the solubility power for the raw formulated flour was 41.23% and the developed products were ranges from 46.3 to 63.2%. The maximum solubility power was recorded for the product Pr7 that was dried at drum temperature of 160°C, drum speed of 200rpm and particle size of 0.6mm. The minimum solubility power 46.3% was observed for product Pr6 that dried at drum temperature of 145°C, drum speed of 300rpm and particle size of 0.8mm. Drying temperature, drum speed and particle size of the product had significant effect ($P < 0.05$) on solubility power of the product.

It was observed that all the drum drying parameters (drum temperature, drum speed) and particle size of the product had a significant effect ($P < 0.05$) on the solubility power of the developed complementary food products. Drying condition and particle size distribution of the product increased significantly ($P < 0.05$) the solubility power of the drum dried complementary food products. Commercial complementary food (Cerefam) has higher solublity (69.38%) than that of the developed anchote based complementary food product was (63.2%).

This may be due to the deferent in raw materials type and the different in their characteristics. As a direct result of flour swelling, there is a parallel increase in the solubility of flour (Onitilo *et al*., 2007). High solubility implies high leaching. The high water solubility of any sample analyzed may be attributed to the degree of swelling power and solubility of the flour provide evidence of non-covalent bonding between molecules within the flour (Rasper1969).

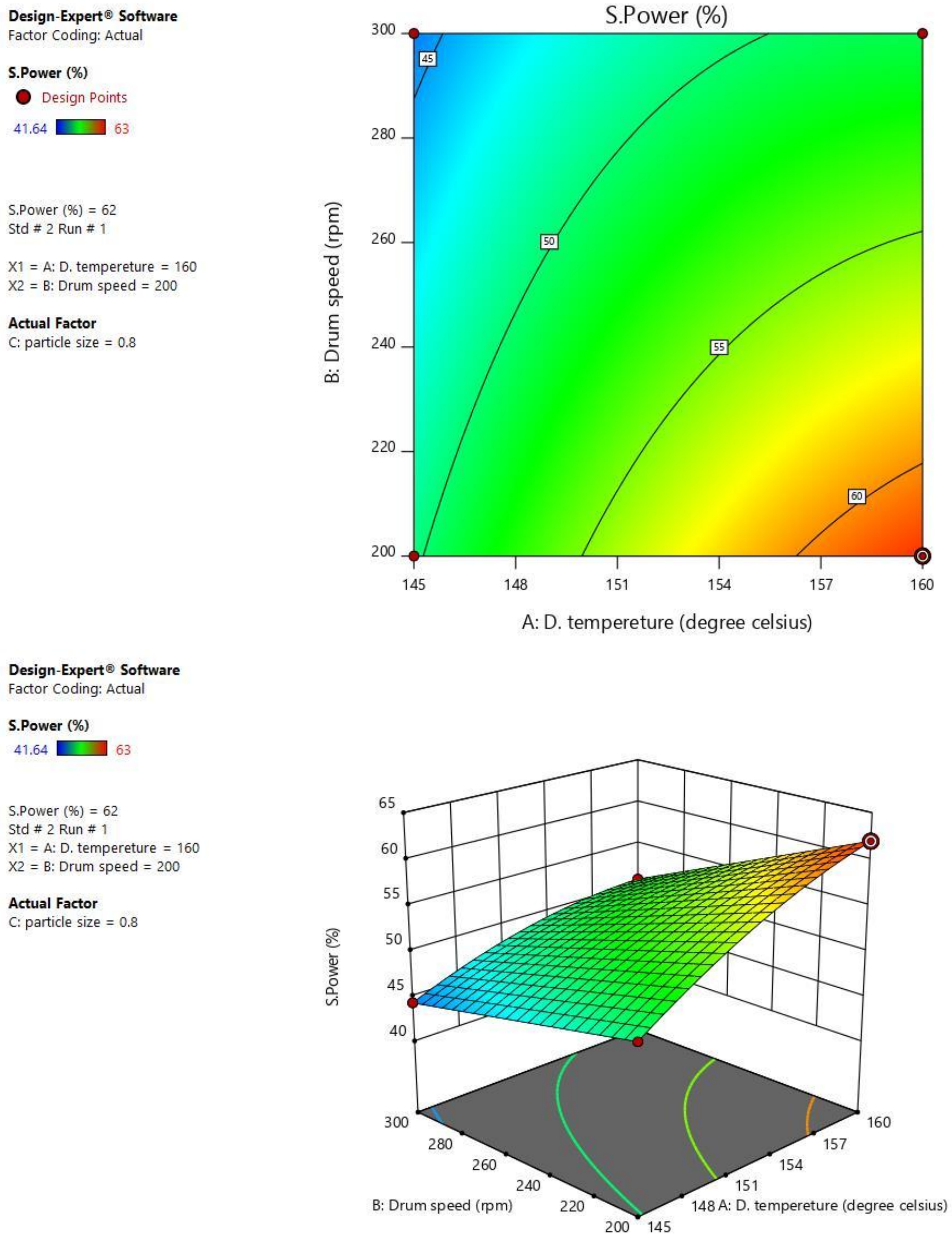


Figure 4.11 Contour and 3D representation of solubility

4.8 Vitamin B2 Content of Anchote Based Ready to Eat Baby Food Product

Riboflavin is naturally present in some foods, added to some food products, and available as a dietary supplement. This vitamin is an essential component of two major coenzymes, flavin mononucleotide (FMN; also known as riboflavin-5'-phosphate) and flavin adenine dinucleotide (FAD). These coenzymes play major roles in energy production; cellular function, growth, and development; and metabolism of fats, drugs, and steroids (Said, HM. *et al.*, 2014).

Table 4.7 Vitamin contents of complementary food product

Parameters	Product code	Vitamin B2 (mg/100g)
Raw formulated flour(Ff)	Rff	0.468±0.00654[a]
160,300,0.6	P1	0.485±0.00146[a]
145,200,0.6	P5	0.472±0.01124[a]

[a] Means with the same superscript letters within a columan are not significantly different ($p>0.05$)
All values are means of triplicate ± standard deviation

The results of the vitamin B2 contents for the raw formulated flour and developed complementary food products were displayed in table 4.7. The raw formulated flour and Drum dried complementary food product had vitamin B2 content of 0.468 and 0.485mg/100g (Table 4.9) respectively. The com-mercial Cerefam complementary food (product Faffa food S.C) had vitamin B2 content of 0.6mg/100g, and the developed anchote based complementary food product had vitamin B2 content of 0.485mg/100g.

According to Codex Alimentarius Standards (FAO/WHO, 2004), the recommended levels (mg/100g) of vitamin B2 for processed cereal based foods for infants and young children ranged from 0.3 to 0.5 mg/100g. On comparing with this standard, the prepared complementary food had vitamin B2 content of 0.48mg/100gram and the commercial Cerefam complementary foods (product of Faffa S.C) had vitamin B2 content of 0.6mg/100gram, respectively which were above the minimum limit (0.3mg/100g) specified in the Codex Alimentarius standards. Drum drying process had no significant effect ($P > 0.05$) on the vitamin B2 contents of anchote based complementary food products and drum tempreture and drum speed no more effect on the availability and reduction of vitamin B2 of the developed products.

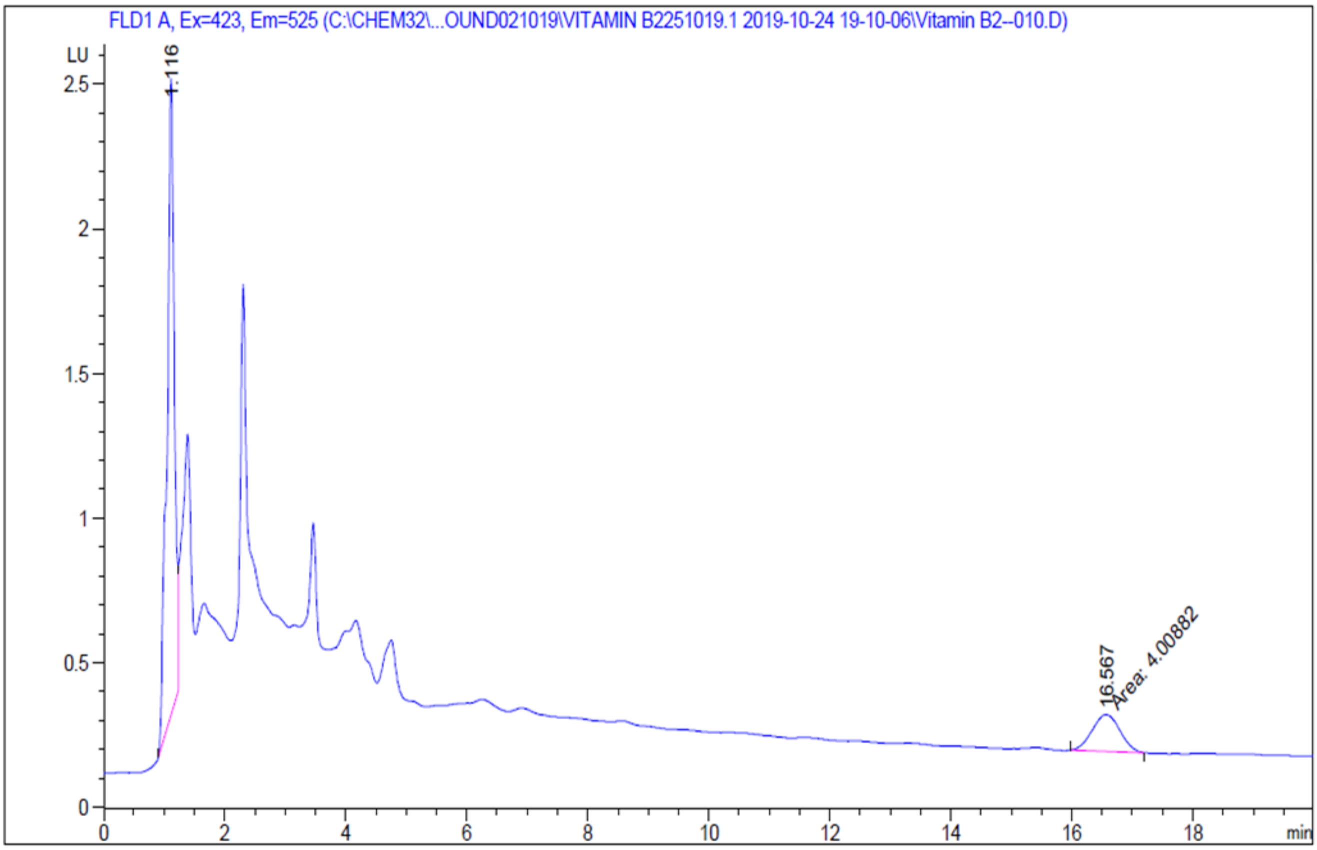


Fig 4.12 Chromatograms of achote based developed ready to eat baby food sample; and chromatographic parameters of the peaks. Chromatographic conditions: column C18 (waters.25cm x 4.6 mm), 5 mm pore size (Merck); mobile phase methanol/water (25:75 v/v) þ 2.5 mM sodium hexanosulfonate and 1.3 triethylamine and 10 ml glacial acetic acid and HPLC water. Detection (fluorescence: excitation wave length: 423nm and emission wave length: 521nm)

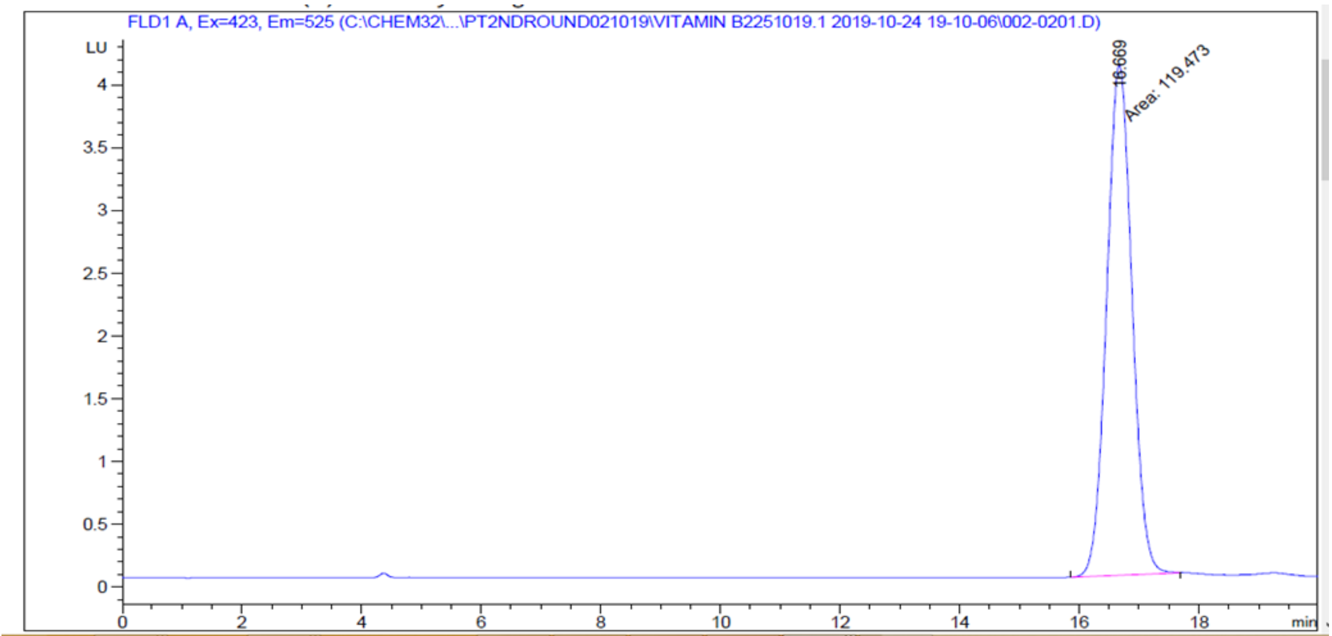


Fig 4.13 Chromatograms of standards of riboflavin ;(injection volume 50µl, flow rate 1.5ml/min and retention time 16 min)

4.9 Mineral Composition of Complementary Food Product

Calcium

The results for the calcium contents of the anchote based developed complementary food products are displayed in table 4.8. The current study showed that the calcium contents of raw formulated flour and drum dried complementary food products were 148.9mg/g and 168.26mg/g respectively. From this results observed that the calcium contents of the developed products were higher than that of raw formulated flour and this showed that there was significant different ($P < 0.05$) between raw formulated flour and developed products. The drum dried complementary food products calcium content ranges from 154.9mg/100g to 168.26mg/100g and from this results observed that there was significantly different ($P < 0.05$) among the drum dried complementary food products due to the drum dry processing temperature of the products.

Calcium content was lowest in the commercial cerefam complementary food, (100mg/100g,) when compared to the developed anchote-based complementary food (168.26 mg/100g) and famix, 80 mg/100g (Table 4.8). Anchote contributed significantly to the calcium content of the anchote based developed complementary food products. The RDI of calcium for infants ranges from 210 to 500 mg/day (Koletzko *et al.*, 2008). It can, therefore, be observed that, besides iron content that anchote flour contributed significantly to the mineral composition of the most preferred complementary food. It is, therefore, very important to complement anchote flour with cereals like oat and legumes such as soybean to improve upon the mineral content in developing complementary foods.

The drum temperature had significant effect ($P < 0.05$) on calcium content of drum dried products and as the temperature increases the Calcium contents of the products increases and the drum temperature may increases the bioavailability of calcium by decreasing ant nutritional factor of the products during drum dry processing. The Ca (mg/100 g) concentration of the commercial famix was 80 ± 0.00, which was lower than the complementary food prepared. The WHO (2013) had also reported the recommended Ca concentration of weaning food to be 400-500 mg/day but not met the weaning food prepared this demand. This is because low Ca concentration of product compared with animal foods and the implication from this is that weaning food should be enriched with high Ca concentration food types such as milk and other Animal food sources.

The Ca and Fe content are higher than the values (22 mg/100g and 1.0 mg/100g) from (Lalude & Fashakin, 2006), of Nutrend – commercial weaning food from Nigeria. The values of Ca, for the developed products are higher than that of (13.1 mg/100g) reported by Edema *et al*. (2005) for maize-soybean blend, and higher than the values (98.2 mg/100g) from the researcher (Bolaj *et al*., 2010) of the production of Ogi.

Table 4.8 Mineral composition of complementary food product (mg/100g)

Parameters	Product code	Ca	Fe	Zn	Mg	K
Formulated flour	RFF	148.9±0.99^{d}	1.2450±0.021^{c}	0.22±0.0141^{c}	81.3± 8.49^{b}	68 ± 0.04^{b}
160,300,0.6	Pr1	160.2±0.884^{b}	1.3765±0.013^{b}	0.425±0.021^{ab}	85.4± 3.30^{d}	58 ± 0.07^{d}
145,200,0.6	Pr3	156.2±0.622^{c}	1.3250±0.07^{d}	0.37±0.014^{b}	83.4± 2.10^{c}	60.6 ± 0.04^{c}
145,300,0.6	Pr5	154.9±0.431^{e}	1.2800±0.014^{c}	0.33±0.014^{b}	82.9± 0.97^{c}	62.2 ± 0.05^{c}
160,200,0.6	Pr7	168.26±0.79^{a}	1.4650±0.021^{a}	0.51±0.042^{a}	86.97±1.20^{e}	54.4 ± 0.03^{e}

$^{a-e}$ Means with the same superscript letters within a columan are not significantly different (p>0.05)
All values are means of triplicate ± standard deviation

Iron

The iron contents of formulated raw flour is 1.24mg/100g and drum dried complementary food products were ranges from 1.28 to 1.46mg/100g respectively. Drum drying process increase significantly ($P < 0.05$) the iron content of drum dried complementary food products. This result occurred may be due to the drum dryer temperature that may increase the bioavailability of the Fe contents of the product by reducing the ant nutritional contents of the drum dried complementary food products. The drum dryer temperature had significant effect ($P < 0.05$) on iron content of drum dried complementary food products and as temperature of the drum dryer increases and the drum speed decreases the bioavailability of the iron contents of product increases. The WHO (2013) recommendation for Fe concentration in the complementary food to be at least 5.8 mg/100 g. but the values of iron and zinc are out of the range of WHP specification (3.25 mg/100g, 5 mg/100g) for the manufacture of corn soya blend for infants. The value of Fe are lower than that of (2.93 mg/100g and reported by Edema *et al.* (2005) for maize-soybean blend.

The iron content of anchote-based developed complementary food product was significantly ($P < 0.05$) lower than cerifam 6mg/100g and famix (6.9mg/100g) commercial complementary foods of Faffa food S.C and this product was fortified with mineral elements and contains animal products. The iron content of anchote based developed product was range from 1.28 to 1.46mg/100 g which was significantly lower than the values obtained for the commercial baby food samples (cerefam complementary food, 6 mg/100g and famix, 6.9 mg/100g). Iron deficiency among infants and young children is common; therefore, the need to have enough iron in the diet of infants. It is required for mental and physical well-being of children, and is needed in the synthesis of hemoglobin in the body. The recommended nutrient intake value for iron in infants between ages of 6 months and 3 years is between 1.7 to 11 mg/day (Koletzko *et al.,* 2008). One hundred gram of the complementary food is, enough to meet the Recommended Daily Intake (RDI) of infants.

Zinc

The results for the zinc contents of the formulated flour and drum dried anchote based complementary food products are displayed in table 4.8. The zinc content of raw formulated flour and drum dried complementary food products were 0.22mg/100g, and ranges from 0.33 to 0.51mg/100g. This results indicates that there was significant difference between raw formulated flour and drum dried complementary food products. Zinc concentration of the processed weaning food found in this work was lower than the range (2.4-10 mg/100 g) reported by FAO/WHO (2010). Zinc is an important micronutrient for infants and young children since it is used in the synthesis of enzymes, hormones, proteins and other materials that promote optimal physical and mental growth. Zinc also enhances the body’s immune system thus, protecting children from infections.

Zinc content of the developed anchote based complementary food product was, lower than that of the commercial cerefam complementary food and famix (5mg/100g). There was significant deference ($P < 0.05$) between the products of drum dried complementary food products that dried at different drum dryer temperatures. The drum dried complementary food product zinc content ranges from 0.33 to 0.51mg/100g. The minimum Zn contents corresponds to products (Pr5 = 0.33mg/100g) that dried at drum temperature of 145^{o}C and drum speed of 300rpm. The maximum values of Zn was recorded to products (Pr7 = 0.51mg/100g) that dried at drum temperature of 160^{o}C and drum speed of 200rpm. The drum drying temperature increases significantly ($P < 0.05$) the zinc content of the complementary food products that dried at different drying temperature.

Potassium

The results potassium contents of the products were showed in the table 4.8. The K contents of raw formulated flour was 68.9mg/100g and drum dried complementary food products ranges from 54 to 62mg/100g respectively and there was significantly different ($P < 0.05$) between raw formulated flour and drum dried complementary food products. The higher level of potassium contents of the developed complementary food product was also 62.2mg/100g. Potassium is required in the body for regulation of fluid, muscle control and normal functioning of the nerves (Nieman, Butter, & Nieman, 1992). The range of potassium content recommended in baby formulas for infants is 60–160 mg/100 g (Koletzko *et al.,* 2008).

Drum dryer had significant effect ($P < 0.05$) on potassium contents of the developed drum dried complementary food products. The minimum K content corresponds to Pr7 product that dried at drum temperature of 160^{o}C and drum speed of 200rpm and the maximum belongs to Pr5 had a K content of 62.2mg/100g. The results show that drum drying process reduced the K content of the drum dried complementary food product significantly ($P < 0.05$). But, the raw formulated flour had higher K content. The potassium salts present in the nutrient solution could have caused this increase in K content (Oboh G. and Elusiyan C. A)

Magnesium

Magnesium contents of drum dried complementary food products were ranges from 82.8 to 86.9mg/100g and the formulated raw flour was 81.3mg/100g. Significant difference ($p < 0.05$) was observed amongst the magnesium content of the developed anchote based ready to eat baby food and formulated raw flour. The drum drying process may improve bioavailability of magnesium contents of drum dried complementary food products. Magnesium level of the developed anchote based ready to eat baby food product was within the range of recommended daily intake and Magnesium was highest in anchote and soybean flour and this may have significantly contributed to the magnesium content of the developed anchote-based complementary food.

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4.10 Antinutritional Factors of Ready to Eat Baby Food

Anti-nutrients are known to reduce the maximum utilization of nutrients especially proteins, vitamins and minerals (Ugwu and Oranye, 2006). So that, the levels of ant-nutritional factors in the anchote based complementary food products are important in the assessment of its antinutritional status.

4.10.1 Phytate

The phytate results of formulated raw flour and complementary food products were analyzed are shown in table 4.9 and the values of phytate contents of raw formulated flour was 190.34mg/100g and drum dried products were ranges from 113.41 to 175.9.mg/100g. There was significant different ($P < 0.05$) between raw formulated flour and drum dried products as observed from the results. Drum drying process reduce the phytate level from 190.16 to 113.41mg/g. It would be expected that lowering this compound should and enhance the bioavailability of minerals such as zinc, calcium and iron.

The potential reason for the decrease in phytate content of the samples during drum drying may be due to the formation of insoluble complexes between phytate and other components, such as phytate-protein and phytate protein mineral complexes or to the inositol hexaphosphate hydrolyzed to penta and tetra phosphates (Siddhuraju and Becker, 2001). Temperature of drum dryer had significant effect ($P < 0.05$) on Phytate contents of drum dried baby food products and drum drying process caused a significant reduction in anti-nutritional factors (tannin and phytic acid) content of the drum dried complementary food produced at different drying temperature and this reduction of phytate increases the bioavailability of minerals and protein content of the products.

As observed from the result significant different ($P < 0.05$) occurred among the drum dried complementary food products that dried at different drum temperature. The minimum phytate contents occurred for the products Pr8 produced at drum temperature of 160^{o}C and drum speed of 200rpm and maximum value of phytate contents of product was occurred for Pr6 that dried at drum temperature 145^{o}C with drum speed of 300rpm.

Table 4.9: Ant nutritional content of raw materials and drum dried product (mg/100g)

Drying parameters	Sample code	Phytate	Tannins
Formulated raw flour	FRF	190.34±2.94[a]	12.23 ± 0.905[a]
160,300,0.6	Pr1	158.01±2.36[c]	4.330 ± 0.495[c]
160,300,0.8	Pr2	159.59±1.09[c]	4.490 ± 0.424[bc]
145,200,0.6	Pr3	139.94±2.28[d]	5.290 ± 0.438[bc]
145,300,0.6	Pr5	170.94±1.71[b]	6.780 ± 0.636[b]
145,300,0.8	Pr6	171.90±1.36[b]	6.850 ±0.863[b]
160,200,0.8	Pr8	113.41±1.33[e]	3.890 ± 0.156[c]

[a-e] Means with the same superscript letters within a column are not significantly different (p>0.05)
All values are means of triplicate ± standard deviation

As described above the reduction in the amount of phytic acid was observed. The Phytate concentration range obtained in the present study is lower compared to the acceptable concentrations. In average, the daily intake of phytate was estimated to be 2000–2600 mg for vegetarian diets as well as diets of inhabitants of rural areas of developing countries and 150–1400 mg for mixed diets (Reddy NR, 2002). But, Hurrel *et al.,* (1992) reported that phytic acid intake of 4-9mg/100g is said to decrease iron absorption by 4-5 folds in humans. Several attempts could be done to reduce anti-nutritional effects of phytate such as soaking, drying, and germination. Phytate present in raw materials and foods of plant origin are suggested to be a major factor responsible for lowering the availability of minerals and some proteins (Shimelis & Rakshit, 2006). Normally encountered levels of phytates in cereals and legumes can reduce protein and amino acid digestibility by up to 10% (Gilani *et al.,* 2012). Phytate containing foods may be a strong contributing factor for poor iron and zinc status in population that consume these diets (Gibson *et al.,* 2010).

4.10.2 Tannins

The results of tannins contents of formulated raw flour and drum dried complementary food products were shown in table 4.9 and the tannin contents of raw formulated flour was 12.23mg/100g and drum dried products were from 3.89, to 6.85mg/100g. There was significant different ($P < 0.05$) between raw formulated flour and drum dried complementary food products as observed from the results. The drum dryer temperature had ($P < 0.05$) significant effect on tannin contents of drum dried complementary food products and as drum temperature increases the tannin content of the product decreases.

Drum temperature had significant effect ($P < 0.05$) on phytate contents of the products. As the drum dryer processing temperature increases, the tannin level of the drum dried product was decreased from 6.85 to 3.89mg/g. It would be expected that lowering tannins compound would increase/enhance the protein, vitamin and the bioavailability of minerals like zinc, calcium and iron. The drum dry processing also showed that some effect on the tannin content of the product by reducing tannins of the drum dried complementary food products and as the temperature of the drum increases from 145^{o}C to 160^{o}C and drum speed decreases from 300 to 200rpm, the tannin level of the drum dried products varied and decreases from 6.85 to 3.89mg/100g.

During the raw material preparation stage, anchote was boiled and also the soybean and oat were thought to have tannin were soaked, dehulled, roasted and grounded before drum dry processing. Therefore, these may be the probable cause for resulted lower tannin value in the final product. The tannin content of legumes ranges from a high value of 2000 mg/100g in faba beans to a low value of 45mg/100g in soybeans (kim *et al*, 2008). But as it is shown in the table the tannin value of the formulated raw flour and the drum dried complementary food product lower than the value of tannin which legumes expected to have. This mainly related to the effects different processing conditions on tannin contents like soaking, dehulling, roasting, backing, grounding and drying of the products at different temperatures.

4.11 Microbial Load of Drum Dried Complementary Food

Microbiological analysis are the most critical parameters which should be conducted for majority of food stuffs. Since products are produced at high temperature processing, the product was less susceptible for microbial contamination. The formulated flour and the drum dried anchote based ready to eat baby food product samples were analyzed for total plate count (TPC), Yeast and mold counts, total coliform and E. coli, based on the NMKL reference methods. The corresponding results of which are then shown in table.4.10.

Coliform and E. coli ware not detected at all in all products. The total plate count and yeast and mold count microbial analysis result was found in the safe limit according to FAO and WHO. From these results we can conclude that both the formulated raw flour and the developed anchote-based ready to eat baby food products were safe for human consumption.

Table 4.10: Microbial quality of raw formulated flour and drum dried ready to eat baby food

Parameters	Inoculation	Pr1(cfu/g)	Pr3(cfu/g)	Pr6(cfu/g)	Pr8(cfu/g)	RFF (cfu/g)
Total plate count (35ºC, 2-3 days)	10-1	15	33	45	13	61
	10-3	10	18	21	6	27
	10-5	3	5	7	2	14
Yeast and molds (25ºC, 5-7 days)	10-1	16	17	30	9	43
	10-3	4	5	10	2	18
	10-5	Nil	1	2	Nil	4
Total coliform (35ºC, 2 days)	10-1	Nil	Nil	Nil	Nil	Nil
	10-3	Nil	Nil	Nil	Nil	Nil
	10-5	Nil	Nil	Nil	Nil	Nil
E. coli count	10-1	Nil	Nil	Nil	Nil	Nil
	10-3	Nil	Nil	Nil	Nil	Nil
	10-5	Nil	Nil	Nil	Nil	Nil

All values are means of duplicate. In the counts < 1 x 101 is the standard reporting format for plates from all dilution of the sample has no colonies (Nil)

Microbial contents of the formulated raw flour and complementary food products were analyzed. In order to check the safety of the products can be contaminated with yeast, mold & total coliform. The results showed that the total coliform and E-Coli contents of the formulated raw flour and drum dried products were not detected. From this result it was not able to see the effect of drum drying process on the total coliform content of the final products. The results showed in the table 4.10, yeast and mold contents of the complementary food products lower than formulated raw flour from (34 to 12 and 4 to nill,) respectively. This result indicated that as drum dryer decreased, the undesirable microorganisms, yeast, mold & total coliform. This shows clearly that the importance of drying in the aspect of food preservation.

The microbial load or levels in the complementary food was low. It was also lower than 2.23 to 3.54 log10 cfu/g reported by Sanoussi *et al.* (2013) in the OFSP-based complementary food with a blend of millet and soybean. The standard for TPC in complementary foods should be less than 2.70 log10 cfu/g (CAC, 2008). Yeast and mould count of the drum dried complementary food product was also low. The standard for yeast and mould in complementary foods has been reported to be less than 2.48 log10 cfu/g for ready-to-eat foods made for infants and 3 log10 cfu/g for foods that require cooking (CAC, 2008).

E. coli count and total coliform were not detected. However, the standard for E. coli in complementary foods should be 0 as reported by CAC (2008). The low microbial count indicates the most preferred sample is safe for consumption. Tang, Feng, and Shen (2003) have reported that the drum drying process can be a clean and hygienic process, if all Good Manufacturing Practices are put in place. Also, if there was any form of contamination during the processing, packaging and storage of the raw materials for the formulation of the complementary foods, the heat being applied by the drum drying reduce the microbial load.

4.12 Sensory Quality

The eight instant complementary food products (Pr1-Pr8) and the control Cerefam wich is cereal based instant baby food from Faffa Food S.C were selected. The sensory attributes considered for the evaluations were color, appearance, odor and test and overall acceptance.

Color

Color provides information about the formulation and quality of the product. The color score of drum dried complementary food ranges from 6.67 - 8. Which is 100 % of the products were rated above 5 implying that the products were accepted by panelists for all independent variables. The preference of the drum dried complementary food formulated, with reference to all parameters given, was between “like slightly (6)” and “accept very much (8)” on the 9-point hedonic scale.

Preference for colour of samples was 8.46 highest in control (Cerefam, Faffa instant complementary food) and Pr7, followed by Pr8 (Table 4.11). The Pr2 was relatively the least preferred (Table 4.11). Color in drum dried products is influenced by temperature, raw material composition and residence time (Guy, 2001). There was significant difference between the color scores of the product at different drying temperature ($p<0.05$).The lowest color score was produced at drum temperature of 145ºC and drum speed of 300rpm. Whereas the highest color scored for the product that dried at drum temperature of 160ºC and drum speed of 200rpm. Generally it was possible to conclude that drum temperature, drum speed and interaction of these variables had significant effect on the color or lightness of the product.

Table 4.11: Sensory evaluation of anchote based ready to eat baby food products

Drying parameters	Sample code	Color	Appearance	Texture	Flavor	Overall Acceptability
160,300,0.6	Pr1	7.133 ± 1.125^{bc}	7.133 ± 1.457^{ab}	7.467 ± 1.302^{a}	6.600 ± 1.639^{b}	7.600 ± 0.986^{ab}
160,300,0.8	Pr2	7.117 ± 1.175^{c}	7.200 ± 1.082^{ab}	7.133 ± 1.060^{a}	6.867 ± 0.990^{b}	7.533 ± 1.060^{ab}
145,200,0.6	Pr3	7.333 ± 0.816^{bc}	7.600 ± 0.986^{ab}	6.933 ± 1.280^{a}	7.133 ± 0.990^{ab}	7.133 ± 0.915^{b}
145,200,0.8	Pr4	7.000 ± 0.926^{b}	6.800 ± 1.014^{ab}	7.133 ± 1.060^{a}	7.00 ± 1.464^{ab}	7.400 ± 1.056^{ab}
145,300,0.6	Pr5	7.067 ± 0.799^{bc}	6.933 ± 1.100^{b}	7.000 ± 1.309^{a}	7.000 ± 1.309^{ab}	7.400 ± 1.242^{ab}
145,300,0.8	Pr6	7.333 ± 1.047^{bc}	7.267 ± 1.335^{ab}	7.067 ± 1.223^{a}	7.000 ± 1.134^{ab}	7.600 ± 1.056^{ab}
160,200,0.6	Pr7	8.000 ± 0.845^{ab}	7.667 ± 0.724^{ab}	7.000 ± 1.254^{a}	7.133 ± 1.246^{ab}	7.133 ± 1.060^{b}
160,200,0.8	Pr8	7.467 ± 1.12^{abc}	6.867 ± 1.060^{b}	7.133 ± 1.246^{a}	7.200 ± 1.474^{ab}	7.400 ± 1.242^{ab}
Cerefam (control)	Control	8.467 ± 0.640^{a}	8.267 ± 0.594^{a}	8.000 ± 0.756^{a}	8.333 ± 0.617^{a}	8.467 ± 0.834^{a}

$^{a\text{-}c}$ Means with the same superscript letters within a column are not significantly different ($p > 0.05$)
All values are means of triplicate ± standard deviation

Appearance

As observed from the table 4.11, the appearance result of the thin porridge (gruel) made from Pr7 was preferred by the panelists with the average value of (acceptable very much) whereas the gruel prepared from Pr6 and Pr3 were ranked second and third with the average value of (like moderately & like moderately).This is due the low viscous nature of the blend upon drying at a temperature of 160^0C.The appearance of the product was improved with increasing drum temperature from 145 to 160ºC, decreasing drum speed from 300 to 200 rpm and increasing particle size from 0.6 to 0.8mm. As presented in table 4.12, the highest (7.67) mean appearance score was obtained at 160ºC drum temperature, at 200 rpm drum speed and 0.8mm particle size. Therefore increase in particle size, increase in drum temperature and decrease in drum speed results in increase in texture value of the developed ready to eat baby food and increase in drum speed and drum temperature results in decreasing the texture value of the product.

Texture

Texture basically was important in determining the consumer acceptability of snacks (Pareyt and Delcour, 2008).The result shows that the mean texture score of baby food product was increases from 6.93 to 7.46 with increasing drum temperature and drum speed. Texture was found to be significantly different among all products. As a result increase in drum speed and drum temperature results in increase in texture value of the product and increase in drum speed results increase in texture value of the product. The least accepted texture of the product was scored 6.93 for product that dried at drum temperature of 145ºC, drum speed of 200rpm and 0.6 particle size content. The highest score for texture was 7.46 and this product was produced at drum temperature of 160ºC, 300rpm and 0.6 particle size of the product.

Flavor

There was significant difference in flavor between developed instant baby food ($p<0.05$) ranges from 6.6 to 7.2. Comparatively, the highest flavor score was 7.2 at 160ºC drum temperature, 200 rpm drum speed and 0.8mm particle size of the product and the lowest 6.6 at 160ºC drum temperature, 300 rpm drum speed and particle size of 0.6mm content. The flavor was mostly influenced by the reaction occurred in between cross linking of starch gelatinization and protein denaturation. From this decrease in drum speed and increase in drum temperature results in increase in texture value of the product and increase in drum speed results in decreasing the flavor value of the product.

Overall acceptability

In General more accepted products for overall acceptability were those product that had relatively higher scores for color, appearance, texture and flavor. Drum temperature was significantly ($p<0.05$) affected the overall acceptability of the product. As shown from table sensory acceptability of the product, the most acceptable complementary food was Pr1 that contains drum temperature of 160ºC, and drum speed of 300rpm content. Overall acceptability of product with mean scores of 7.6 (like very much). The sensory results indicated that the product produced at drum temperature of 160ºC, and drum speed of 300 rpm and particle size 0.6mm was perceived as the most accepted product, as compared to the other drum dried product with different drying conditions. As discussed above, the drum dryer temperature and drum dyer speed had significantly affected overall acceptability of the developed anchote based rady to eat baby food ($p<0.05$). Since any new product must give satisfaction and pleasure to the consumers, sensory attributes were also considered during selecting optimum process condition.

CHAPTER FIVE

CONCLUSIONS AND RECOMENDATION

5.1 Conclusions

Infant malnutrition is an imperative health problem in Ethiopia. Proper nutrition is important to ensure growth and development of infant. Most of the supplementary baby foods are imported here in Ethiopia and these baby foods are usually beyond the affordable limit of people. Low cost local food ingredients were used to prepare a low cost complementary food to meet the nutritional requirements of growing infant. The formulated and developed baby food was found nutritionally rich and safe in microbial point of view with low production costs comparable to imported and other commercials baby foods. Anchote based ready to eat baby food was also accepted by the test testing panel. This complementary food could be an alternative of imported baby foods to meet the nutritional requirements of infants.

This study has shown that anchote plant can be employed to produce acceptable and improved nutritional contents of food products from oat and soybean, which can be used as complementary foods. The most preferred formulation for the anchote based raedy to eat complementary food was the blend with 54.11% anchote flour, 26.67% oat and 19.76% soybean flours. It had significantly ($p < 0.05$) higher protein (18.68%) and energy (399.8kcal) contents than the cerefam commercial complementary food with protein14% and energy content of 396kcal. The vitamin B2 contents of anchote based developed ready to eat baby food product had 0.48mg/100g respectively and this product meet the nutritional requirements recommended by WHO/FAO.

The product was safe to consume because it was able to meet the microbial standards set by Codex Alimentarius Commission. Anchote flour could be used to develop a complementary food with improved nutrient properties, when complemented with oat and soybean flours. This when adopted, will help with protein deficiency in Ethiopia and also increase the utilization of anchote to help achieve food and nutrient security. Drum drying affected the physic-chemical and functional properties of anchote based ready to eat baby food. The developed anchote based ready to eat baby food that processed at a drum temperature of 145^{o}C, drum speed of 200rpm and 0.6mm particle size distribution has high nutritional value and energy contents.

Even though drum drying involves high temperature processing, this method was able to produce drum-dried anchote based baby food that was rich in protein and carbohydrate, combined with good mineral retention and good functional properties. This product has the potential to act as a functional food that can be consumed easily by infants. Thus, drum drying process is a best alternative for producing instant complementary food with high commercial value. Food processing, especially of staple foods like cereals, legumes and roots, can have important beneficial effects on the nutritional value of foods given to children with moderate malnutrition

5.2 Recommendations

The following issues should also be considered in the future based on the outcomes of the current study.

- ❖ It is recommended that the optimization of the drum drying process conditions (drum temperature, drying time and drum speed) in the development of the anchote based complementary food and the shelf life study of anchote-based complementary food could be studied.
- ❖ A full study should be conducted on the effect of the drying process on the amino acids and the protein digestibility index of the product
- ❖ Further studies on the shelf life and packaging materials, which enable good handling of the product, should be carried out.
- ❖ Further study should be conducted on urease activity and i*n vivo* protein digestibility test to further check and compare the quality of anchote based instant complementary food with other commercial complementary foods.
- ❖ Study and suggesting suitable and economical production, product transportation and storage equipment's.

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Appendix I proximate composition of the augmented matric

Run	A:Anchote	B:Oat	C:Soybean	Moisture	Ash	Fiber	Fat	CHO	Protein%	Energy (kcal)
	%	%	%							
1	60	25	15	6.22	4.5	4.4	4.05	64.63	16.20	359.77
2	45	40	15	6.5	4.12	4.2	5.5	63.77	15.91	368.22
3	49.5	25	25.5	5.06	3.98	4.43	6.5	60.21	19.51	377.39
4	30	40	30	5.07	3.99	4.1	7.05	59.73	20.06	382.61
5	40.4912	39.0854	20.4234	6.27	4.06	5.1	5.46	62.07	17.04	361.89
6	60	25	15	6.22	3.99	4.4	4.05	64.32	16.20	359.77
7	*54.1166*	*26.5968*	*19.867*	*5.01*	*3.51*	*4.0*	*5.99*	*63.52*	*18.01*	*380.03*
8	45.0829	33.3979	21.5192	5.85	4.05	4.53	5.48	60.64	19.45	369.68
9	40.4216	29.5784	30	6.26	4.32	4.7	6.63	57.63	20.46	372.03
10	40.4216	29.5784	30	6.26	4.32	4.7	6.63	57.63	20.46	372.03
11	35.1381	40	24.8619	6.13	4.12	4.72	5.9	59.71	19.42	369.62
12	45	40	15	6.5	4.12	4.2	5.5	63.77	15.91	368.22
13	35.3132	34.6868	30	5.81	4.13	4.46	6.97	58.03	20.60	377.25
14	51.9958	33.0042	15	5.42	3.73	4.26	5.24	64.93	16.42	372.56
15	30	40	30	5.07	3.99	4.1	7.05	59.73	20.06	382.61
16	49.5	25	25.5	5.06	3.98	4.43	6.5	60.21	19.51	377.39

Appendix II ANOVA for protien

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	51.26	9	5.70	228.21	< 0.0001	significant
(1)Linear Mixture	48.38	2	24.19	969.23	< 0.0001	
AB	0.3189	1	0.3189	12.78	0.0117	
AC	1.33	1	1.33	53.13	0.0003	
BC	0.7985	1	0.7985	32.00	0.0013	
ABC	0.2382	1	0.2382	9.54	0.0214	
AB(A-B)	0.4367	1	0.4367	17.50	0.0058	
AC(A-C)	1.03	1	1.03	41.38	0.0007	
BC(B-C)	1.14	1	1.14	45.53	0.0005	
Residual	0.1497	6	0.0250			
Lack of Fit	0.1497	1	0.1497			
Pure Error	0.0000	5	0.0000			
Cor Total	51.41	15				

The **Model F-value** of 228.21 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A, B, C, AB, AC, BC, ABC, AB (A-B), AC (A-C), BC (B-C) are significant model terms.

Appendix III ANOVA for energy

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	787.87	8	98.48	24.05	0.0002	significant
(1)Linear Mixture	353.21	2	176.61	43.12	0.0001	
AB	84.02	1	84.02	20.51	0.0027	
AC	135.67	1	135.67	33.13	0.0007	
BC	187.46	1	187.46	45.77	0.0003	
A^2BC	77.62	1	77.62	18.95	0.0033	
AB^2C	98.29	1	98.29	24.00	0.0018	
ABC^2	24.46	1	24.46	5.97	0.0445	
Residual	28.67	7	4.10			
Lack of Fit	28.67	2	14.33			
Pure Error	0.0000	5	0.0000			
Cor Total	816.53	15				

The **Model F-value** of 24.05 implies the model is significant. There is only a 0.02% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A, B, C, AB, AC, BC, A^2BC, AB^2C, ABC^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

Appendix IV Fit summery for protein

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Mean vs Total	5447.18	1	5447.18			
Linear vs Mean	48.38	2	24.19	103.76	< 0.0001	
Quadratic vs Linear	**1.60**	**3**	**0.5330**	**3.72**	**0.0495**	**Suggested**
Sp Cubic vs Quadratic	0.0792	1	0.0792	0.5271	0.4863	
Cubic vs Sp Cubic	**1.20**	**3**	**0.4008**	**16.06**	**0.0028**	**Suggested**
Quartic vs Cubic	0.1497	1	0.1497			Aliased
Residual	0.0000	5	0.0000			
Sp Quartic vs Quadratic	0.7183	3	0.2394	2.35	0.1586	
Quartic vs Sp Quartic	0.7131	2	0.3566			Aliased
Residual	0.0000	5	0.0000			
Total	5498.58	16	343.66			

Appendix V Fit summery for energy

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Mean vs Total	2.213E+06	1	2.213E+06			
Linear vs Mean	353.21	2	176.61	4.96	0.0251	
Quadratic vs Linear	2.89	3	0.9634	0.0209	0.9956	
Sp Cubic vs Quadratic	**371.77**	**1**	**371.77**	**37.74**	**0.0002**	**Suggested**
Cubic vs Sp Cubic	59.96	3	19.99	4.18	0.0645	
Quartic vs Cubic	28.70	1	28.70			Aliased
Residual	0.0000	5	0.0000			
Sp Quartic vs Quadratic	**431.76**	**3**	**143.92**	**35.14**	**0.0001**	**Suggested**
Quartic vs Sp Quartic	28.67	2	14.33			Aliased
Residual	0.0000	5	0.0000			
Total	2.214E+06	16	1.384E+05			

Appendix VI Model Summary Statistics for protein

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	0.4828	0.9410	0.9320	0.9242	3.90	
Quadratic	**0.3783**	**0.9722**	**0.9582**	**0.9332**	**3.43**	**Suggested**
Special Cubic	0.3876	0.9737	0.9562	0.9133	4.46	
Cubic	**0.1580**	**0.9971**	**0.9927**	**0.5046**	**25.46**	**Suggested**
Special Quartic	0.3192	0.9861	0.9703	0.8461	7.91	
Quartic	0.0000	1.0000	1.0000		*	Aliased

Appendix VII Model Summary Statistics for energy

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	5.97	0.4326	0.3453	0.1621	684.21	
Quadratic	6.79	0.4361	0.1542	-0.3137	1072.71	
Special Cubic	**3.14**	**0.8914**	**0.8190**	**0.7115**	**235.61**	**Suggested**
Cubic	2.19	0.9649	0.9121	-4.9765	4880.03	
Special Quartic	**2.02**	**0.9649**	**0.9248**	**0.5477**	**369.36**	**Suggested**
Quartic	0.0000	1.0000	1.0000		*	Aliased

Appendix VIII Point predictor for energy and protein

Two-sided Confidence = 95% Population = 99%

Response	Predicted Mean	Predicted Median	Observed	Std Dev	SE Mean	95% CI low for Mean	95% CI high for Mean	95% TI low for 99% Pop	95% TI high for 99% Pop
Protein	20.0399	20.0399		0.157973	0.159501	19.6496	20.4302	18.9486	21.1313
Energy	374.144	374.144		2.02371	1.79717	369.895	378.394	361.371	386.917

Appendix X Coefficients in Terms of Coded Factors

Component	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
A-Anchote	360.20	1	1.41	356.85	363.54	2.54
B-Oat	301.33	1	17.10	260.89	341.76	126.66
C-Soybean	203.41	1	35.62	119.18	287.64	527.69
AB	148.96	1	32.89	71.19	226.73	60.24
AC	318.51	1	55.34	187.65	449.36	152.53
BC	521.09	1	77.02	338.97	703.22	290.69
A^2BC	-989.19	1	227.22	-1526.48	-451.91	7.40
AB^2C	-2053.34	1	419.13	-3044.43	-1062.26	25.04
ABC^2	1069.92	1	437.83	34.62	2105.21	33.47

.

Appendix XI Pictures during work

Figure raw material processing and anchote, oat and soyabean flour preparation at EFDA and AASTU

Figure anchote based instant baby food preparation using drum dryer at Addis Ababa Science and Technology University.

Figure the final product of anchote based instant baby food

Microbial, proximate, mineral, vitamin, functional and physic- chemical analysis

Figure Sensory analysis at Faffa food Share Company

Appendix XII Sensory score card using nine point Hedonic scale for snack samples

Panelist code/name: ______________ date: _____________ Age: ______________

You are presented with food samples. Please taste and evaluate according to how you feel about the sample

Characteristics

1=dislike extremely 2=dislike very much 3=dislike moderately 4=dislike slightly 5=neither like nor dislike 6=like slightly 7=like moderately 8=like very much 9=like extremely

Overall acceptability

Desirability

1=extremely unacceptable 2=very much unacceptable 3= moderately unacceptable 4=slightly unacceptable 5=neither acceptable nor Unacceptable 6= acceptable slightly 7=acceptable moderately 8=acceptable very much 9=acceptable extremely

Characteristics & desirability	Sample Code	Pr1	Pr2	Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9
Color										
Appearance										
Texture										
Flavor										
Overall Acceptability										
Remark										

Appendix XIII Methods of microbial load determination in food products.

A. Determination of aerobic colony count for mould and yeast (NMKL, No. 98, 1997)

Method principle

The aerobic colony count estimates the number of viable aerobic mould and yeast per g or ml of product. A portion of the food homogenate is mixed with a specified agar medium and incubated under specific conditions of time and temperature. It is assumed that each viable aerobic mould/ yeast will multiply under these conditions and give rise to a colony.

Procedure:

- Preparation of food homogenate Transfer 10ml of liquid sample to 90ml of diluents or 25g of sample to 225 ml of diluents in a flask if shaker used or in sterile plastic bag if stomacher used to make 101 dilution (the first dilution)
- Dilution
  - Mix homogenate by shaking and pipette 1ml into a tube (labled102 containing 9ml of normal saline. Mix carefully by aspirating 10 times with a pipette
  - From the first dilution, transfer with the same pipette 1ml to 2nd dilution tube containing 9ml of the Ns, Mix with a fresh pipette
  - Repeat using 3rd or more until the required numbers of dilutions is made
  - Shake all dilution carefully.
- Pour plating
  - Pipette 1ml of the food homogenate and of each dilution of the homogenate into each of the appropriately marked duplicate dishes.
  - Pour into each petridish 15-20ml of the PDA.
  - Mix the sample dilution and agar medium thoroughly and uniformly, allow solidifying.
- Incubation. Incubate the prepared dishes, inverted, at 370C and 220C for 5-7 days.
- Counting the colonies. Following incubation, count all colonies on dishes containing 30-300 colonies and recorded the results per dilution counted.

Verification: If there is growth on the negative control or if there is no growth on the positive controls the test should be repeated.

Expressions of results: calculate the average count and multiply by the dilution. And express the result in cfu per g –ml (if a liquid sample).

The result at 37^0C reported as yeast and mold count at 37^0C.

The result at 22^0C reported as yeast and mold count at 22^0C.

B. Determination of Aerobic Plate Counts in food (NMKL, No. 86, 2006)

Method principle

The aerobic colony count estimates the number of viable aerobic bacteria per gm or ml of a product. A portion of the diluted sample mixed with a specified agar medium and incubated under specific temperature for 48 hr. It is assumed that each viable aerobic bacterium will multiply under these conditions and give raise to colonies.

Terms:

- Mesophillic bacteria: an organism whose optimum growth lies within a range generally accepted as 20-45^{0}C
- Psychrophilic bacteria: an organism which grows optimally at or below 15 ^{0}C, which has an upper limit for growth at 20 ^{0}C , and which has a lower limit of 0 ^{0}C or lower.
- Termophilic bacterial: an organism whose optimum growth temperature is >45 ^{0}C

Procedure:

- Sample preparation Transfer 10ml of liquid sample to 90ml of diluents or 25g of sample to 225 ml of diluents in a flask if shaker used or in sterile plastic bag if stomacher used to make 101 dilutions (the first dilution) Mix well with shaker/stomacher
- Dilutions Mix the first dilution by shaking then pipette 1ml into a tube (labled102) containing 9 ml of normal saline. Mix carefully by aspirating 10 times with a pipette.
- From the 102 dilution, transfer with the same pipette 1ml to the tube (labled103) containing 9ml of the diluent, Mix with a fresh pipette. Repeat until the required numbers of dilutions are made.
- Pour plating Pipette 1ml of each serial dilution into each of the appropriately marked duplicate dishes. Pour 15- 20ml of the molten PCA kept at 45 0C into each Petri dish. Mix it thoroughly and allow it to solidify.
- Incubation. Incubate the dishes, inverted, at 35 0C or for dairy products at 320C for 48 hr. N.B: Avoid excessive humidity in the incubator, to reduce the tendency for spreader formation, but prevent excessive drying of the medium by controlling ventilation and air circulation. Agar in plates should not lose weight by more than 15% during 48 hours of incubation.
- Counting the colonies. Following incubation, count all colonies within the range of 30- 300 colonies and record the results per dilution counted.

Sample preparation: weigh 10g of the sample in to a sterile 250ml Erlenmeyer flask; marked to indicate 100ml volume. Add sterile saline peptone to 100ml mark. Dissolve and shake thoroughly.

- Dilution: 1:10, 1:100, 1:1000, etc
- Dilution factor: 1 x 101, 1×102, 1× 103 etc
- Inoculation: Pipette 1ml of the food homogenate and of each dilution of the homogenate into each of the appropriately marked duplicate dishes followed by pour plating of PCA.
- Incubation: Incubate the prepared dishes, inverted, at 350C for 48 hours and for dairy products at 320C for 48 ± 3 hrs.
- Counting colonies: Following incubation, count all colonies on dishes containing 30-300
- Colonies, including those of pinpoint size and recorded the results per dilution counted.
- Verification: If there is growth on the negative control and /or no growth on the positive control the test should be repeated with the corrected media
- Expression of results: express the result in cfu per g /ml (if a liquid sample)
- Calculation formula: Use the best two consecutive dilutions, as n1 and n2 to calculate the results.

N =C/V (n1 + 0.1n2) d

Where, C = is the sum of colonies on all plates counted

V = is the volume applied to each plate

n1= is the number of plates counted at first dilution.

n2= is the number of plates counted at second dilution,

d = is the dilution from which first count was obtained.

N= is the average plate count.

Round the result to two significant figures and express it as a number between 1.0 and 9.9 multiplied by 10 x where x is the appropriate power of 10.

C. Enumeration of coliform (MPN) (NMKL, No. 44, 2004)

Method principle

Graduated amount of food (diluted) sample are transferred to a series of fermentation tubes containing lactose or lauryl sulphite tryptose broth of proper strength, it is usual practice to inoculate to three fermentative tubes. The tubes are incubated at 35+ 0.5 0C for 24 and 48hrs.The formation of gas in any of the tubes with in 48hr ,regardless of the amount, constitutes as positive for coliform and the absence of gas formation with in this period considered as negative for coli form . Confirm the coliform by BGBB.

Procedure:

Presumptive test for coliform group (MPN)

- Preparation of the first dilution (10^1)

  Transfer 10ml of liquid sample to 90ml of diluents or 25g of sample to 225 ml of diluents in a flask if shaker used or in sterile plastic bag if stomacher used to make 101 dilution (the first dilution) and Mix well with shaker/stomacher. Mix homogenate by shaking and pipette 1ml into a tube containing 9 ml of normal slain. Mix carefully by aspirating 10 times with a pipette. From the first dilution, transfer with the same pipette 1ml to 2nd dilution tube containing 9ml of the Ns, Mix with a fresh pipette. Repeat using 3rd or more until the required numbers of dilutions are made. Shake all dilution carefully.
- Inoculation

  Inoculate each of 3 replicate tubes of LSTB broth per dilution (containing inverted tubes) with 1ml of the previously prepared 1:10, 1:100 and 1:1000 dilutions using sterile pipette for each dilution.
- Incubation: Incubate the LSTB tubes at 35+ 0.5 0C for 48hrs.
- Reading: Record tubes showing gas production after 48hr
- Result reading: Record all tubes showing gas within 48 + 2hrs and refer to MPN table for the 3 tube dilution and report results as the presumptive MPN of coliform bacteria per g (or ml of liquid product).
- Confirmed test for coliform group (MPN): Subculture all positive tubes showing gas within 48 + 2 hours 2 hours in to BGB broth by means of the 3 mm loop. Incubate all BGB tubes at 35 + 0.5 0C for 48 + 2 hours. Record all BGB tubes showing gas, and refer to the MPN table for 3 tube dilution. Report results as confirmed MPN of coliform bacteria per g (or ml of liquid product). Coliform bacteria per g (or ml of liquid product).

***D.* Determination of coliforms, fecal coliforms and *E. coli by using MPN technique* (FDA/BAM, 2006)**

50 g of the sample was weighted into sterile high-speed blender jar. Frozen samples can be softened by storing it for <18 h at 2-50C, but do not thaw. 450 ml of Butterfield's phosphate buffered and water were blended for 2 min. If <50 g of sample are available, weigh portion that is equivalent to half of the sample and add sufficient volume of sterile diluents to make a 1:10 dilution. The total volume in the blender jar should completely cover the blades.

Decimal dilutions with sterile Butterfield's phosphate diluents were prepared. Number of dilutions to be prepared depends on anticipated coliform density. Shake all suspensions 25 times in 30 cm arc or vortex mix for 7s. Do not use pipettes to deliver <10% of their total volume. Transfer 1 ml portions to 3 tubes for each dilution for at least 3 consecutive dilutions. Hold pipette at angle so that its lower edge rests against the tube. Let pipette drain 2-3s. Not more than 15 min should elapse from time the sample is blended until all dilutions are inoculated in appropriate media. Incubate tubes at 350C. Examine tubes and record reactions at 24 ± 2h for gas, i.e., displacement of medium in fermentation vial or effervescence when tubes are gently agitated. Re-incubate gas negative tubes for an additional 24 h and examine and record reactions again at 48 ± 2 h. Perform confirmed test on all presumptive positive (gas) tubes.