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ECONOMIC POTENTIALS OF UNDERUTILIZED STAPLES FOR SUSTAINABLE INFANT NUTRITIONAL REQUIREMENTS IN NIGERIA

Delivered by

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Being the text of the 4th Inaugural Lecture delivered at the Federal University Oye-Ekiti

The Vice-Chancellor

Deputy Vice-Chancellor Academics

Deputy Vice-Chancellor Administration

The Acting Registrar and other Principal Officers

Deans of Faculties

Eminent Scholars here present

Members of the University Community

My Royal Fathers here present

Friends of the University

Gentlemen of the Press

Distinguished Ladies and Gentlemen

It is with great gratitude to the almighty GOD for making me see this day in the history of my academic career. It is with great humility for me to stand before you all to deliver the 4th . inaugural lecture of our University. I therefore welcome everyone present to rejoice with me on this unique occasion.

PREAMBLE

My journey to academia is full of intrigues. I attended Christ's School, Ado-Ekiti, arguably the best school in the world! I was very passionate about Art subjects because late Pa Oloketuyi, my literature teacher and my father's classmate told me I was smarter than my father. Meanwhile, before this revelation, my father would say he was always first in his class which on childlike enquiry, Pa Oloketuyi refuted. Therefore, how did I find myself offering science subjects? I was instructed by my father to do so, because it was the vogue at that time and to add to this injury was when I got the 23rd position at the end of the year examination. This earned me the name *'twenty tiri position'* wickedly given to me by my mother. She would not call me that except when visitors were around. This geared me to obtain the 7th position in the next major examination.

After my secondary school, my father forced me to go for Higher School Certificate (HSC) at Ekiti Parapo College, Ido-Ekiti. I hated the idea and of course passed only one course. Daddy was advised that I should repeat HSC but I refused. I did the entrance examination of University of Ibadan (UI), Jos campus and got 59% instead of 60% required from southerners for admission when 45% was required from northerners! I ran to daddy to please talk to his friend, late lawyer Odumuye, the then Registrar of UI. Daddy said, '*sorry you should have scored 70%'*. I then ended up doing part-time course in Science Laboratory Technology at the University of Ibadan (UI). As if that was not enough, daddy did not believe I was doing any tangible course until I got admission to the Agricultural and Mechanical (A&M) University, Huntsville, Alabama, United States of America (USA), to study Biological Science majoring in Microbiology at Masters Level. He gladly sponsored my education in the United States of America. It is on the premise of the given preamble that I welcome you to my world of exploits in Science.

INTRODUCTION

My Vice Chancellor Sir, it is indeed a great pleasure for me to present this Inaugural Lecture entitled: **"Economic Potentials of Under- Utilized Staples for Sustainable Infant Nutritional Requirements in Nigeria"** which I dedicate to GOD the FATHER, SON and HOLY SPIRIT. Sir this is the first in the history of the Department of Food Science and Technology and in the Faculty of Agriculture of this our Great University. After the stone age (about 8,000 years ago), man began with revolutionary changes which developed into the quest of finding edible grains and tubers. In brief, it is now a matter of urgent attention as our infants nutritional need continue to expand and food sufficiency has become a global challenge.

Adequate nutrition of infants is very crucial to the achievement of the Sustainable Development Goals (SDGs) in Nigeria. Malnutrition in infants can lead to future physically and cognitively challenged infants that set them behind throughout life time. Undernourished infants have lower resistance to infections, a less resilient immune system, and are more likely to die from common childhood ailments. One of the four strategies recommended by

WHO, UNICEF (2005) is fortification of infant complementary foods for use after six (6) months of exclusive breastfeeding.

Introduction of Complementary Foods

Complementary food is the food given to infants after exclusive breast feeding for six (6) months (UNICEF 2005). Around six (6) months of age, the mother's breast milk may not provide adequate calories and nutrients for the child's growth **(Oyarekua 2011)**. Introducing solid foods before an infant is six months of age may interfere with the child's ability to take in adequate amounts of nutrients and calories (WHO 1989).

However by six (6) months of age, the structure of the mouth in the infant is well developed and the tongue extrusion reflex which pushes out non-liquid food disappears and the infant is ready to accept semi-solid foods. Complementary food must be of correct consistency, soft digestible diet containing adequate calories, proteins, micronutrients, free of microbial contamination, easy to prepare, easily accepted by the infant, at an affordable cost and must be of a quantity that can be consumed at one feeding **(Oyarekua 2008).**

In Nigeria, the first complementary food is usually a thin cereal gruel called 'ogi' made from fermented maize, millet or sorghum. Compositionally, cereals consist of 12-14 % water, 65-75% carbohydrates; 2-6% lipids and 7-12% protein on dry weight basis. They are also significant contributors of vitamins and minerals.

The Nigerian fermented ogi have an average energy density of 0.26 kcal/g **(Oyarekua 2014)** instead of the energy density of the range of 0.7 to 1.0 kcal/g which is considered as an acceptable energy density for infants (Svanberg 2002).

Weaning with this low energy density foods like ogi can unintentionally reduce nutrient intake and expose the infant to faltering growth and specific nutrient deficiencies **(**Cohen 1994, **Oyarekua 2010)**.

The resolution of Codex Alimentaruis Commission, CAC (1991) prescribes the nutritional regulations for the requirements, processing and manufacturing techniques, hygiene rules, for use in the processing of infants complementary foods provided such foods are staple of such country and that they would be complemented with breast milk feeding of the infant. However, all these regulations are too difficult to be met by traditional or low socio-economic mothers and even some local food industries that specialize in complementary food processing.

Millet **wheat** **Cowpea** **Maize** **Walnuts**

Carrot **Bitter yam** **Sorghum** **Sweet potato**

Plate 1 Some Nigeria Staples

Fermentation: Traditional spontaneous fermentation is the oldest food-processing technology dated back to 6,000 B.C. Spontaneous food fermentations are typically carried out by microorganisms involving mixed cultures of bacteria, yeasts, or both **(Oyarekua 2013)**. Spontaneous fermentation lends itself to easy application especially at cottage level where literacy level is generally low (**Oyarekua *et al*. 2007**). The proteolytic activity of bacteria in traditional fermentations degrades complex proteins into peptides, and amino acids **(Oyarekua *et al.* 2008)**. Fermentation also provides a way of preserving food products, destroys anti-nutritional factors, enhances nutritive value, improves appearance and taste of some foods and reduces energy required for cooking. (**Oyarekua 2011, 2010**).

Cereal (700g) + Legume winnowed (300g)

↓

Soaking in 3000ml distilled water for 72h (Microbial isolation at every 24hours)

↓

Milled fermented mixture

↓

Sieving using a muslin cloth

↓

Re-washing and re-sieving of residues

↓

Further fermentation for 24hours (microbial isolation after 24hours)

↓

Sedimentation

↓

Dewatering

↓

Paste / cake

↓

Sundry for 48 hours

↓

Milling and sieving

↓

Flour (final product)

Fig: 1 Flowchart for a typical Co-fermentation process

The Use of Starter Cultures

Starter cultures are also used in fermentation process. *Lactobacillus plantarum* is probably the most commonly used bacterium as a starter culture in the production of fermented foods. It has an advantage of utilizing sugars at high conversion rate to lactic acid (Fu and Mathews 1999). In a study on 'gari' production, Giraud *et al.* (1993) isolated what he called A6, a strain of *L. plantarum* from retted cassava. Furthermore, Agati *et al.* (1998) isolated a new strain christened OgiE-1 from among amylolytic hetero fermentative lactic acid bacteria from the 'mawe' dough of Benin Republic in West Africa. I was privileged to be among the first few scientists to work on these starter cultures. In my work, I investigated these two starter cultures and also used natural inoculums (NI) from naturally fermented maize as pure cultures in the co-fermentation of maize/cowpea blend with the aim of improving the nutritional quality and increasing the consistency thereby increasing the energy density. It should be noted that many food staples in Nigeria are under-utilized for infant consumption because our culture/tradition does not encourage their use as infants' complementary foods.

MY CONTRIBUTION TO KNOWLEDGE

Mr. Vice Chancellor Sir, permit me to present some aspects of my research works over the years. The Bible says *'all things are lawful but not all things are expedient'* 1ST Corinthians 6 verse 23. The nutrients that will be revealed in these works though beneficial, limits / levels are required from complementary foods because the infants are expected to still be fed with breast milk along with these complementary foods. We have to avoid overloading the infants with nutrients in order to avoid toxicity or infant obesity. Therefore, the actual nutritional values of my work were interpreted based on the level of required nutrients from complementary food on low, average, and high breast milk intake by the infants as recommended by WHO/FAO/UNU (1998). Also Exiguity *et al.* (2007) recommended that cereal/legume blend should be in ratio 700g cereal to 300 legumes. This was the ratio I used for co-fermented cereal/legume in my work.

I have in most of my research work explored many under-utilized staples not currently used as infant complementary foods, this I did by co-fermenting two or more substrates using the modification of traditional fermentation processes to improve the nutritional quality of infant complementary foods process as shown in figure.1. What are the essential nutrients required for infants growth and are they available in Nigeria's staples? Yes, these are water, quality proteins in terms of amino acids, lipids, crude fiber, minerals and vitamins. Also apart from working on these essential nutrients, my research was also extended to determination of viscosities and organoleptic properties of such foods and has also focused on encouraging low-socio economic mothers to improve the nutritional status of their infants at affordable costs.

The work was divided into various groups as follows:

a) Co-fermented cereals/legume

b) Co-fermented cereal/cowpea using pure isolated Starter cultures

c) Co-fermented tuber/legume

d) Co-fermented cereal/legume/tuber

e) Co-fermented tuber/legume/vegetable

MY FINDINGS

In the study of pH changes during 0-72 hours fermentation time

Figs 2-5 show the effects of fermentation on the pH changes during fermentation process of some staples.

An inhibitory pH range of food-poisoning bacteria is considered to be 3 to 4 **(Oyarekua 2004)**. The period required to reach this range is governed by fermentation duration, nature of substrate, micro flora, fermentation temperature and ratio of water to substrates in fermenting medium (**Oyarekua 2009**).

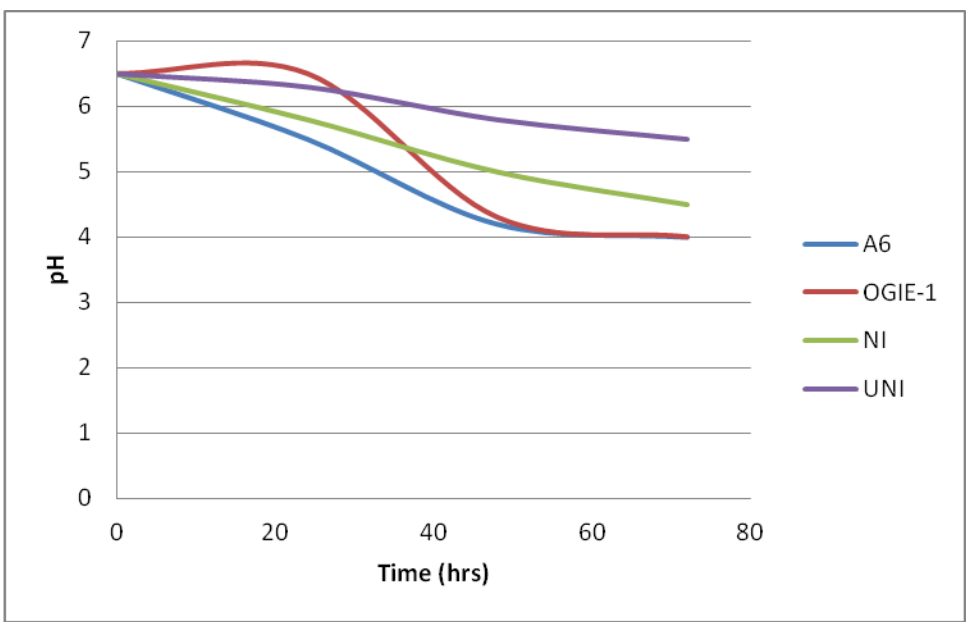

Fig.2: pH graph of co-fermented maize/cowpea using starter cultures

Key: A6= Co-fermented maize/cowpea using A6 Starter culture, Co-fermented maize/cowpea using OGIE-1 Starter culture, Co-fermented maize/cowpea using Natural inoculum as starter culture, UNI= Co-fermented maize/cowpea without the use of starter culture.

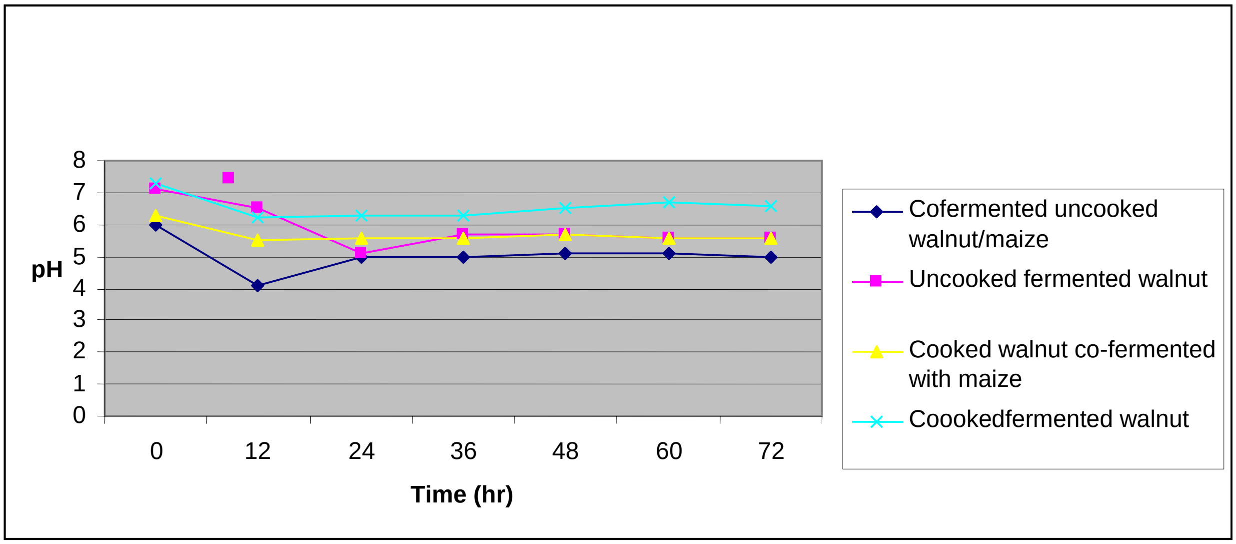

Fig. 3: Effects of cooking and co-fermentation of walnut/maize on pH changes

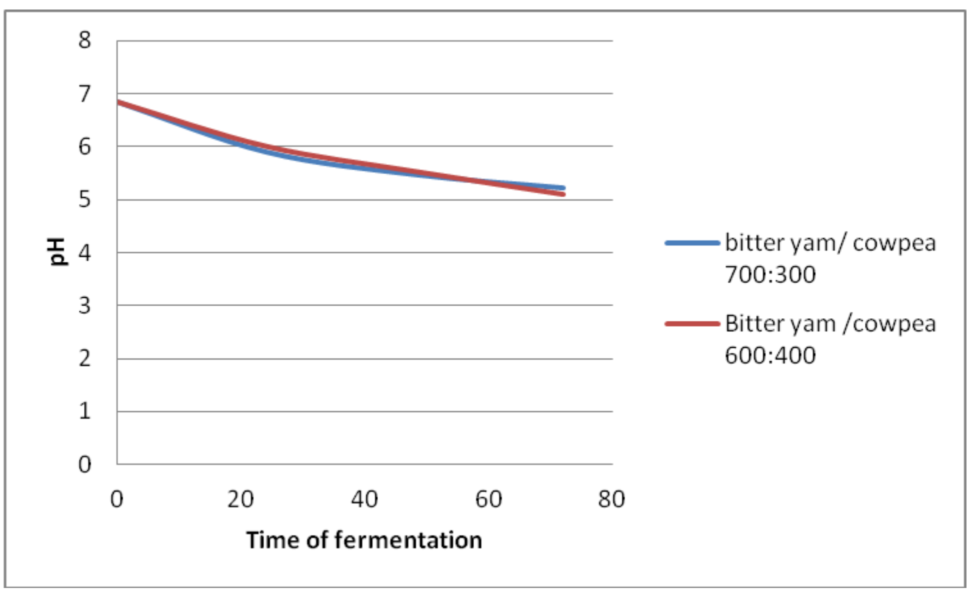

Fig 4: pH changes during the co-fermentation of bitter yam /cowpea in different ratios

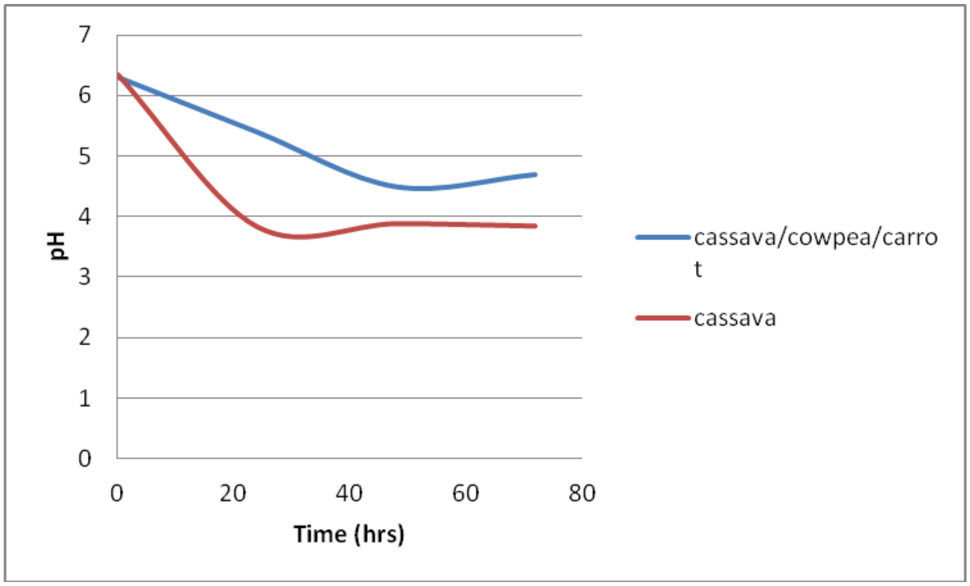

Fig.5: pH changes during the co-fermentation of cassava/cowpea/carrot

In fig. 2: In using starter cultures: The pH values of A6, OGIE-1 was 4.0 at 72 hr and NI was 4.5 **(Oyarekua 2008).**

Fig 3: The pH of co-fermented raw maize & walnut (RWM) moved from initial 6.3 at 0 hour to 5 by 72 hours of fermentation. while the co-fermented cooked walnut and maize (CWM) was 6 at 0 hour to 5.5 at 72h fermentation time. The slight pH increase in CWM might be due to inactivation of some microbial activities by heat during the cooking of the walnut (**Oyarekua** and Bamkefa **2016**).

Fig 4: There was no difference in the pH changes in bitter yam/cowpea in 700:300 ratios and 600:400 ratios. The pH of both was 5 at 72 hours of fermentation time. This showed that difference in formulation ratio had no effect on the changes in pH changes over 72 hours of fermentation.

Fig. 5: Cassava/cowpea/carrot: cassava ogi had its pH value drop from 6.4 at 0 hour to 3.8 by 72 hour of fermentation time. The co-fermented mixture pH value dropped from about 6.3 at 0 hour to 4.7 by 72 hours. The presence of cowpea and carrot in the co-fermented mixture must have contributed alkalinity to the fermenting medium due to hydrolysis of the protein molecules; thus raising the pH **(Oyarekua 2013).**

Proximate Composition

The routine proximate chemical analysis of foods is also called the proximate or Weende Analysis (Oyeleke, 1984). Estimations are based on nitrogen (as an index of crude protein), water, fat, ash and crude fibre; the sum of these subtracted from 100g, is the carbohydrate by difference.

Table 1: Proximate composition of samples based on study groups (g/100g)

Group	Sample	Total ash	Moisture Content	Dry matter	Crude protein	Crude fat	Crude fiber	Carbohydrate
A	**FERMENTED CEREAL/LEGUME**							
(1)	Germinated maize co-fermented with cowpea	0.94	12.14	87.86	12.50	5.74	4.31	64.37
	Ungerminated maize co-fermented with cowpea	1.06	9.78	90.22	5.74	2.88	0.12	80.42
(2)	Co-fermented Raw walnut with maize(RWM)	3.28	4.33	95.47	20.51	7.58	0.93	63.17
	Cooked walnut co-fermented with maize(CWM)	16.98	5.88	94.12	19.25	6.76	0.64	50.39
(3)	Co-fermented millet/cowpea (LM/C)	1.88	12.93	87.07	11.20	2.82	2.31	68.86
	Unfermented millet/cowpea(UMC)	3.85	11.20	88.80	14.0	3.20	5.34	62.41
	Co-fermented sorghum/cowpea (LSC)	0.85	10.16	89.84	10.6	2.70	4.35	71.34
	Unfermented sorghum/cowpea(USC)	2.42	10.90	89.10	13.8	4.26	4.94	63.68
B	**CO-FERMENTED CEREAL/LEGUME USING STARTER CULTURES**							
(4)	(A6MC)	2.05	9.58	90.42	15.20	5.49	3.38	64.30
	(OGMC)	1.24	10.02	89.98	14.59	4.71	3.73	65.71
	(NIMC)	1.18	9.98	90.02	13.48	3.98	5.13	66.25
	(UNMC)	0.59	9.68	90.32	12.26	3.48	4.45	69.54

C	**CO-FERMENTED TUBER/LEGUME**							
(5)	Co-fermented bitter-yam/cowpea ratio 700:300	1.01	8.59	91.41	18.85	3.64	1.01	66.90
	Co-fermented bitter-yam/cowpea ratio 600:400	0.44	9.93	90.07	17.40	3.97	0.66	67.60
	Unfermented bitter-yam/cowpea ratio 700:300	1.55	10.87	98.13	19.64	6.41	0.51	61.02
	Unfermented bitter-yam/cowpea ratio 600:400	1.76	11.54	88.46	17.40	3.29	0.36	65.65
D		**CEREAL/TUBER/LEGUME**						
(6)	cassava/cowpea/carrot ogi	0.599	5.66	94.34	9.88	3.12	1.63	79.15
	Cassava ogi	0.343	1.21	98.70	9.86	9.59	1.48	77.51

Moisture Content

Mr. Vice Chancellor Sir, water is life and infants also require it for body temperature regulation and transport route for nutrients. However, the water needs of infants under normal circumstances are met from consuming breast milk and complementary foods. Infants may receive an insufficient amount of water if the flour concentration is too high leading to difficulty in digestion which might lead to constipation.

Water plays an important role in the excretion of waste products by the infant's kidneys, however, conditions such as vomiting, diarhoea, and sweating can lead to dehydration thus such infant needs supplemental water from breast milk and complementary food. We should also note that excessive water in the diet can lead to water intoxication which can occur in infants who consume infant complementary food that is over-diluted with water like 'ogi' in Nigeria. Symptoms of water intoxication include irritability, or sleeplessness, hypothermia, edema, and seizures. Also, infants fed excessive water will not receive adequate kilocalories to meet their needs for growth and development. In my work, water content was considered as dry matter which is 100grams minus value of moisture content.

Dry Matter: The dry matter content of any food substance assist in maintaining the quality of such food **(Oyarekua** and Eleyinmi **2004)**. Several reports indicate that the dry matter loss during fermentation is influenced by solids: water ratio, the nature of microorganisms involved and the hydrophobic and hydrophilic nature of the substrates **(Oyarekua 2009).** Most reports on natural fermentation of cereals are based on 1:4 solids: water ratio, which appears to be rather high. In my study, a ratio 1:3 solid to water was used because the less the volume of water in the fermenting medium, the higher the levels of acids present, inhibiting the growth of pathogens (**Oyarekua 2009**).

In the study of co-fermenting germinated maize and ungerminated cowpea, the co-fermented germinated sample had lower dry matter compared to ungerminated mixture. Germination process must have contributed to the reduction of dry matter. Incidentally, traditional mothers are vast in grain germination process **(Oyarekua 2008, Oyarekua 2014).**
For co fermentation of raw walnut/maize and cooked walnut/maize: The lower dry matter content of co-fermented cooked walnut/maize might be due to water contribution during cooking.

In cereal/legumes: The co-fermented sorghum/cowpea had lower dry matter than the millet/cowpea counterparts. The structural make up of sorghum must have influenced the reduced dry matter **(Oyarekua 2009).**
In the use of starter cultures: the dry matter of the mixtures with starter cultures of A6, OGI-E1 compared favourably with the mixture with natural inoculum as seen in Table 1.
For co-fermented Bitter yam/cowpea studies: Bitter yam, locally called 'esuru' for long has been regarded as adults' food. Why must infants be left behind? As **tuber/legume** I co-fermented bitter yam with cowpea in various ratios to examine the nutritional quality as infants' complementary food.
The ratio of 700:300 had higher dry matter than that of 600: 400 therefore the 700:300 ratio is more appropriate in terms of keeping quality after co-fermentation process.

On the study of Co-fermentation of cassava/cowpea /carrot ogi: Have we ever heard of cassava *'ogi'*? No is likely to be the answer. I co-fermented cassava/cowpea/carrot and fermented cassava ogi as control; the dry matter contents were also comparable in both samples as seen in Table 1 **(Oyarekua 2009).**

Proteins:

Functions of protein: Infants require high quality protein from complementary foods to maintain, repair and build new tissues for all the body organs. Proteins are also important in the manufacture of enzymes, hormones and antibodies. Protein serves as a potential source of energy if the diet does not furnish sufficient kilocalories from carbohydrate or fat. When an infant starts receiving a substantial portion of energy from food other than breast milk then the complementary foods is expected to provide adequate protein.

Cereals are high in methionine and low in lysine while legumes are low in methionnine and high in lysine when both are eaten at the same time sufficient amounts of all the essential amino acids can be made available to the body **(Oyarekua 2008**).

Protein deficiency: Infants who are deprived of nutritionally adequate foods for long periods of time may develop kwashiorkor, resulting from protein deficiency; or marasmus, a deficiency of kilocalories; or marasmus-kwashiorkor, deficiency of kilocalories and protein **(Oyarekua 2008).**

Crude Protein

Oyarekua and Adeyeye **(2008)** reported that fermentation reduced crude protein but not protein quality in terms of amino acids and bioavailability. **WHO/FAO/UNU (1998),** recommend 10g/100g crude protein from complementary foods for 6-23 months old infants.

In **germinated and un-germinated co-fermented mixtures:** The mixture with germinated maize had higher value of crude protein than the mixture with ungerminated maize. The value of co-fermented mixture is comparable to Recommended dietary allowance (RDA) value. Therefore germination followed by fermentation might meet the crude protein value required for 6-23 months old infants **(Oyarekua 2008).**

In co-fermented cooked and raw walnut with maize, CWM and RWM had comparable values and the values were higher than RDA for complementary foods for 6-23 months old.

For co-fermented cereal/cowpea: Co-fermentation reduced crude protein in co-fermented millet/cowpea and sorghum/cowpea when compared with their unfermented analogues, I observed that co-fermentation did not affect the crude protein value in co-fermented mixture as shown in Table 1 **(Oyarekua 2010)**. This finding was contrary to the report of Ache *et.al.* (2008), who reported that supplementation before fermentation (co-fermentation) improved protein. My finding was due to hydrolysis of protein to amino acids (**Oyarekua** and Adeyeye **2009**).

In the evaluation of the use of three starter cultures mixture of maize/cowpea A6, OGIE-1 and mixture NI. The mixture using A6 had higher crude protein and the values of mixtures using A6 and OgiE-1 met the Codex (1994) recommendation of 10-15 g crude protein (cp)/100 g dry weight for complementary foods. This suggests that the use of *L. plantarum* A6 and *L. fermentum* OGIE-1 can be effective in increasing the protein content of co-fermented maize/cowpea (**Oyarekua *et al.* 2008).**

In co-fermented bitter yam/cowpea in different ratios: In the ratio of 700:300 both co-fermented and the unfermented mixtures had higher crude protein values than those of 600:400. However the values of crude protein in all the samples exceeded the required values for 6-23 months old infants as seen in Table. 1.

Lipid: Lipids are a group of chemicals including fats and oils. Lipids are major sources of energy, and allow for the absorption of the fat-soluble vitamins A, D, E, and K (EUR/00/5018028 CINDI dietary guide). Lipids provide essential fatty acids that are required for normal brain development, healthy skin, normal eye development, and resistance to infection and disease. Complementary foods in Nigeria are often low in lipids **(Oyarekua 2010,** Adeyeye, Orisakeye and **Oyarekua 2010)**.

The Codex standard for processed cereal-based foods for infants and young children (CODEX STAN 2006) recommends that lipids of complementary food should not exceed 3.3g fat /100 kcal at the level of average breast milk intake.

Lipid in germinated and un-germinated co-fermented mixtures: GMCO had higher lipid content than UGMCO **(Oyarekua 2014)**

For raw walnut/maize and cooked walnut/maize: RWM had comparable lipid values with CWM. Therefore, the crude fat contents in the RWM and CWM samples are an advantage since they contain essential oils (**Oyarekua** and Bankefa **2016**).

The use of three starter cultures mixture: The lipid contents of unfermented mixtures were significantly lower (P<0.05) than those of A6MC, OgiE-1 and NI. However maize/cowpea A6 and OGIE-1 had higher but comparable lipid values than NI.
The higher values of lipid co-fermented mixtures with the use of starter cultures of A6 and OGIE-1 compared to the use of NI may be directly attributed to the amylolytic activities of the starter culture used. A6 had a slightly higher value than others in its lipid contents **(Oyarekua** *et al.* **2008**).

For co-fermented bitter yam/cowpea in different ratios: The lipid contents in the ratios of co-fermented bitter yam/cowpea, 700:300 and 600:400 and their corresponding unfermented mixtures met the standard values for 6-23 months old infants (**Oyarekua 2016**).

In co-fermenting cassava/cowpea/ carrot: lipid content was significantly (p>0.05) higher in fermented cassava ogi than co-fermented cassava/ cowpea/ carrots ogi. This might be due to greater water absorption capacity in the matrix of cassava.

Crude Fibre

Dietary fibre is found in legumes, wholegrain foods, fruits, and vegetables. It is the edible portion of plant material that human gastro intestinal enzymes cannot break down. Infants generally consume no fibre in their first 6 months of life because breast milk has no fibre. As complementary foods are introduced to the diet, fibre intake increases.

According to Protein Advisory Group (PAG) of the United Nations (1993), an upper limit of 5% crude fibre in complementary food per day is desirable and therefore recommended 2%

per day in cereal/legume blends. Global Alliance for Improved Nutrition (GAIN) (2008), also advised that grains meant to be used as infant complementary food should be milled before processing for consumption to keep the fibre and other antinutrients at a minimum. Milling was done on all the products in my work as shown in figure 1.

In the study on co-fermentation of germinated maize/ungerminated cowpea: Germinated maize/ungerminated cowpea was 4.31g/100g and 0.12 g/100g for un-germinated maize/cowpea. Since Protein Advisory Group (PAG) (1993) suggests an upper limit of 5% crude fiber in complementary food, therefore the low fibre content of GMCO will be desirable for infants because high fibre levels lower calorie density, reduce digestibility, inhibit vitamin and mineral bioavailability (**Oyarekua 2011**).

In co-fermentation of raw walnut /maize and cooked walnut/maize: The crude fiber of RWM and CWM were very low at 0.93 and 0.64 g/100g respectively (**Oyarekua** and Bankefa **2016**).

In co-fermented cereals/cowpea: The co-fermented and unfermented samples of sorghum/cowpea had higher crude fibre values than their millet/ cowpea counterparts. The testa of sorghum that is harder than that of millet might have contributed to the higher fibre content of the mixtures. The mixture of millet/cowpea should be preferred for use as an infant complementary food in terms of crude fibre reduction (**Oyarekua** and Adeyeye **2009**).

In the use of starter cultures: The values of crude fibre in the use of starter culture A6 an OGIE-1 were comparable and they are in the range of RDA for complementary foods for 6-23 months old infants (**Oyarekua** *et al.* **2008**).

For **bitter yam/cowpea in different ratios**: Crude fibre value of 700/300 ratio was higher than in the ratio 600:400. Therefore, the ratio formulation is important in the amount of crude fibre present in the mixture **(Oyarekua 2016**) however the crude fibre contents in all the ratios were lower than 2% recommended for cereal/legume blend **(Oyarekua 2009)**.

For co-fermented cassava/cowpea/carrot samples and fermented cassava: As presented in Table 1, the values of crude fiber in this study were comparable in both samples; but both values were lower than 4g /100 g recommended for 6-12 months old infants.

Carbohydrate:

Cereals/cowpea co-fermentation: The carbohydrate content of all co-fermented samples decreased compared with unfermented analogues **(Oyarekua 2010**). This agrees with the observation of Sefa-Dedeh (2001) and Mbata *et al.* (2009); that addition of legumes decreased carbohydrate of cereal-based traditional foods.

In bitter yam/cowpea in different ratios: The mixture of 700/300 had slightly higher values of carbohydrate compared to the ratio of 600/400.

Co-fermented cassava/cowpea/carrot and cassava ogi: Carbohydrate value in the co-fermented cassava/cowpea/carrot and cassava ogi had high and comparable carbohydrate values.

Carbohydrates fall into three major categories: monosaccharides, disaccharides and polysaccharides. Carbohydrates are necessary in the infant's diet for food energy supply, growth, body functions, and activities (**Oyarekua** and Ketiku **2010**). Carbohydrates also allow efficient utilization of protein in the diet.

Processing operations involving steaming and fermentation increase the digestibility of starch, rendering it more susceptible to enzymatic digestion (**Oyarekua 2010**). Thus, it is expected that the carbohydrates of all the co-fermented products would be readily digestible since they would be boiled before consumption after being subjected to fermentation process. Infants who consume sufficient breast milk and appropriate complementary foods will meet their dietary needs for carbohydrates (**Oyarekua 2011**).

Minerals

Protein energy malnutrition is not deficiency of protein and energy only, but of some nutritionally important minerals **(Oyarekua 2016).** Minerals are components of key enzymes. The body uses mineral ions as electrolytes to help regulate, muscle and activities of all organs, maintain the delicate cellular fluid balance, formation of bone and blood cells, to provide for electrochemical nerve activity, to regulate the distribution and acidity of its fluids **(**Adeyeye and **Oyarekua 2012)**. Loss of minerals during the fermentation in *ogi* production was reported by (Akingbala *et al.* 1981). Important minerals analyzed in my studies were phosphorus, zinc, magnesium, calcium, iron, sodium and potassium as shown in Table 2.

Table 2: Major Mineral Content of Samples Based on Grouping (mg/100g)

GROUP	Sample	P	Na	K	Ca	Mg	Fe	Cu	Zn	Mn
A	**CO-FERMENTED CEREAL/LEGUME**									
(1)	Raw walnut/maize	8.34	15.7	32.4	81.6	163	2.34	0.010	70.3	8.34
	Cooked walnut/maize	3.08	12.7	20.5	65.5	108	1.22	0.030	58.4	3.08
(2)	Lab.co-fermented millet/cowpea (LM/C)	128	5.60	77.8	31.6	16.2	34.7	0.470	1.41	0.810
	Lab. unfermented millet/cowpea (UM/C)	127	2.00	640	40.5	133	7.92	0.420	3.40	0.840
	Lab. co-fermented sorghum/cowpea (LS/C)	178	4.00	75.2	20.6	56.6	14.2	0.460	1.400	0.930
	Lab. unfermented sorghum/cowpea(US C)	181	2.00	135	49.2	217	6.10	0.610	3.60	2.06
B	**CO-FERMENTED CEREAL/COWPEA USING STARTER CULTURES**									
(3)	Co-fermented maize/cowpea with A6 starter culture (A6MC)	1944	204	3311	183	1127	86.1	4.25	13.9	N D
	Co-fermented maize/cowpea with OGE-1 starter culture (OGMC)	7903	236	3112	145	728	42.8	ND	ND	ND
	Co-fermented maize/cowpea with natural inoculum	1442	130	2903	171	953	28.8	4.91	4.91	ND

	starter culture (NIMC)									
	Unfermented maize/cowpea with natural inoculum starter culture (UNMC)	1352	71.2	676	155	152	23.3	3.11	3.11	N D
C	**CO-FERMENTED TUBER/LEGUME**									
(4)	Co-fermented bitter yam/cowpea 700:300	ND	188	219	416	416	7.63	ND	2.24	1.00
	Co-fermented bitter yam/cowpea 600:400	ND	325	463	490	ND	8.52	ND	2.26	1.28
	Unfermented bitter yam/cowpea 700:300	ND	202	441	565	ND	4.25	ND	6.94	1.74
	Unfermented bitter yam/cowpea 600:400	ND	438	513	717	ND	5.76	ND	2.86	2.24
D	**CEREAL/VEGETABLE/LEGUME AND CEREAL/TUBER/LEGUME**									
(5)	Cassava/cowpea/carrot	ND	7.50	2.80	44.9	3.80	2.10	0.054	0.110	1.40
	Cassava 'ogi'	ND	9.80	4.90	53.4	4.90	2.90	0.073	0.710	2.00

ND = Not Determined

Zinc: Zinc is a part of every cell in the body and forms part of over 200 enzymes that function in body hormones and cell growth. Sufficient levels of zinc are needed for the body's immunity and strength. Zinc has antiviral activity against several viruses that cause the common cold. Zinc functions in blood, brain, heart, healing, carbohydrate digestion and transportation of vitamin A (Livnyl *et al*. 2003). Zinc deficiency is prevalent in infants in Nigeria because their diets are low in animal products. The deficiency of zinc can reduce the immune response, loss of appetite and growth retardation. Diarrhea can also cause intestinal zinc loss (WHO/NUT/1998). The RDA of 3mg is recommended for cereal-based infants diets in developing countries. Zinc values were evaluated in the food mixture using both Krebbs and British standards methods **(Oyarekua 2009)**.

In the co-fermented walnut/maize study: RWM had significantly (p0>0.05) higher value of zinc (70.3mg/100g) than CWM (58.2mg/100g) (**Oyarekua** and Bankefa **2016**).

Zn in co-fermentation of cereals/cowpea: In this study, the zinc values were lower in co-fermented samples than their unfermented analogues. The zinc values in the unfermented analogues met the requirement for 6-8 months and 9-11 months old infants using Krebs's Standard (**Oyarekua 2010)**.

Zn in the use of starter cultures: Zinc contents were significantly higher (P>0.05) in the mixture that had A6 while mixture with OgiE-1 had no detectable amounts. That Zn was not detected in the use of OGE-1 suggests that Zn may be needed for the optimal growth and activity of *L. fermentum* OgiE-I. Hence, it would be necessary to supplement OgiE-1 diets with good zinc sources (**Oyarekua,** *et al.* **2008)**.

Phosphorus: The recommended dietary allowance (RDA) of phosphorus from complementary food ranged from 141-362mg/d depending on infant age and level of breast milk intake. Phosphorus combines with calcium to give rigidity to bones and to maintain blood neutrality **(Oyarekua** and Eleyinmi **2004**). Out of the 800grammes of phosphorus in your body, about 80 % of that is in your bones. The other 20% is used for processes like the metabolism of red blood cells, and production of adenosinetriphosphate (ATP) in the energy cycle.

Deficiency of phosphorus can lead to lack of appetite, general tiredness and muscle pain.

Phosphorus deficiency is common in malnourished children and severe hypophosphatemia is associated with increased mortality in kwashiorkor cases (**Oyarekua** and Eleyinmi 2004).

Phosphorus in co-fermented cereal/cowpea: In Table 2, the values was higher in millet/cowpea than sorghum/cowpea. Values of co-fermented millet/cowpea could meet the requirement of 141mg/d for 12-23 months old on high breast milk intake, while that of sorghum/cowpea could meet the requirement of 193mg/d for 12-23months old on average breast milk intake **(Oyarekua** and Adeyeye **2008).** My result in this study is contrary to the finding of Brooks (2009) that fermentation release phosphorus bound by phytate in fermented liquid feeds. However, the consumption of all co- fermented samples in this work can easily meet the body's phosphorus requirement.

In the use of starter cultures: The phosphorus value in co-fermented mixtures using starter cultures was higher in A6 starter culture than others. Generally the use of starter cultures significantly (P<0.05) improved the mineral composition with respect to Phosphorus (**Oyarekua** *et al.* **2008**).

Calcium: Calcium is believed to be critical in determining the course of fermentation process. Calcium in the body is contained in the bones, but about 1% is used for nerve impulses and muscle contractions that sustain life and provide movement. Calcium is also an important mineral in blood clotting (**Oyarekua** and Eleyinmi **2004**). Low calcium intake in infants may induce rickets and growth retardation. Average daily intake of calcium from complementary food for infants on average breast milk intake should be 336mg/d for 6-8mo, 353mg/d for 9-11 and196mg/d for 12-23 months old, and values above this per day may stress the kidney and may result in kidney stone **(Oyarekua 2009).**

In the study on walnut/maize: Calcium content was more enhanced in RWM with a value of 81.58mg/100g than CWM of 65.5 mg/100g (**Oyarekua** and Bankefa **2016)**.

In the use of starter cultures: Mixture with A6 had higher content of calcium as shown in Table 2 (**Oyarekua** *et al.* **2008**).

Calcium results in co-fermented bitter yam/cowpea: Values showed that **t**he co-fermented mixtures in different ratios had lower calcium levels than the unfermented mixtures. This is contrary to the report of Oyewole and Odunfa (1990) that reported that fermentation released bound calcium. But the mixture of ratio 600:400 had enhanced value of calcium than that of 700: 300 thus ratio of bitter yam and cowpea played an integral role in calcium distribution (**Oyarekua 2016**).

Iron

The evaluation of iron: Iron intake is considered inadequate in infants because of low iron content of breast milk and rapid growth rate in infants. Iron mainly functions in the hemoglobin in red blood cells. Its deficiency leads to anemia, mal-absorption of foods, fatigue pallor, depressed growth, impaired psychomotor development and abnormal functioning of the brain. The adverse effect of anemia like depressed growth persists even if the anemia is corrected during infancy. Iron can be accessed in many different types of food, but only 10% of all dietary iron is absorbed through the small intestine into the blood. Non-heme iron is found in cereals and legumes and infants receive most of iron as non-heme iron. Complementary food should provide a quantity of iron sufficient to meet the RDA of 11 mg for infants aged 7 to 12 months and 7 mg for toddlers (Lynch and Stoltzfus 2003, **Oyarekua 2009**).

On the iron contents of walnut/maize mixtures CWM and RWM: It was observed that co-fermenting raw walnut with maize yielded double iron content compared to that of cooked walnut with maize (**Oyarekua** and Bankefa **2016**).

Iron in co-fermented cereals/cowpea: As seen in **Table 2,** Fe levels were generally higher in co-fermented millet/cowpea and sorghum/cowpea samples than unfermented samples **(Oyarekua 2010).** This is because fermentation hydrolyses ferric to ferrous leading to increase in iron content this increase was associated with higher ferrous content in co-fermented samples **(Oyarekua** and Adeyeye **2009)**. My finding is in agreement with earlier report that fermentation increase iron availability by a factor of 2-6 (Egli *et al.* 2003, Hemalatha *et al.* 2007). The iron values in this work were higher than RDA of 17.8mg/100g for infants on low breast milk intake and 9.13 mg/100g for infants on medium breast milk intake.

In the use of starter cultures: Mixture with A6 starter culture gave a significantly higher level of iron than the other starter cultures (**Oyarekua** *et al.* **2008**).

On the study of Co Fermented Bitter Yam and Cowpea as Complementary Food. The values of iron in this work might be desirable for infants of 9- 11months in the sample of ratio 600:400. This shows that the ratio of the tuber and legume may play an important role in the content of extractable iron in the mixture (**Oyarekua 2016**).

Table 3: Amino acid (mg/g cp) profile of samples based on grouping

Amino Acids	GM/CO	UGM/CO	Cassava /cowpea/carrot	Cassava ogi	RW/M	CW/M	M/C	S/C
Arginine	40.0	19.6	285	207	9.89	8.24	36.3	44.3
Histidine	24.0	10,3	164	79	2.55	2.24	20.9	22.8
Cystine	19.0	8.4	73	46	2.53	7.29	19.9	21..3
Tryptophan	4.0	3.8	ND	ND	ND	ND	ND	ND
Methionine	36.0	21.7	81	47	2.39	2.74	19.6	30.9
Phenylalanine	37.0	28	111	77	4.37	4.56	41.9	51.5
Tyrosine	21.0	28	79	64	2.19	2.51	30.4	40.3
Leucine	78.0	39.3	254	158	7.89	7.09	101	129
Isoleucine	18.0	21.8	149	89	3.64	4.19	35.9	38.2
Valine	17.0	13.7	156	90	4..66	5.10	46.0	52.9
Threonine	ND	ND	135	80	3.30	3.82	29.4	32.9
Serine	ND	ND	60	30	5.28	4.61	40.1	45.2
Glutamic acid	ND	ND	863	1007	19.0	19.3	170	200
Aspartic acid	ND	ND	316	205	8.80	8.90	57.5	68.8
Proline	ND	ND	183	41	5.52	4.77	66.9	88.9
Glysine	ND	ND	149	89	4.57	4.01	25.0	31.8
Alanine	ND	ND	204	44	4.64	4.88	70.8	81.8
Lysine	ND	ND	111	92	2.09	2.59	101	129

ND = Not Determined.

Amino Acids

Amino acids are the "building blocks" of the body. When protein is broken down by digestion the result is 22 known amino acids. Nine amino acids are essential that is they cannot be manufactured by the body. The rest are non-essential (can be manufactured by the body with proper nutrition) **(**Adeyeye, Orisakeye and **Oyarekua 2011)**. The essential amino acids (EAAs) are histidine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine; they also include cystine and tyrosine which are considered essential for infants. Besides building cells and repairing tissues, amino acids form antibodies to combat invading bacteria and viruses; they are part of the enzyme and hormonal systems; they build nucleoproteins (RNA and DNA). If all the amino acids are not present within a close of 2 to 3 hour period protein assimilation will not work. For example, if one amino acid is only present at the 60% level the assimilation of all amino acids will be limited to that 60% level **(Oyarekua and Akinyele 2011).** Amino acid (protein) deficiency symptoms are: weak immune system, loss of antibody production, fatigue, stomach acid/alkaline imbalance, and dizziness/nausea.

Table 4. Amino acids quality parameters of samples (mg/gcp)

Parameter	GM/ CO	UGM /CO	RWM	CWM	LMC	LSC	Cassava/ cowpea /carrot	Cassava 'ogi
TAA	294	194.6	1839	968.4	912.6	1109.6	3373	2445
TEA with Histidine	254	175	357.6	421.3	447.5	548.8	1313	822
TEAA/TAA	0.86	0.89	0.19	0.46	0.41	0.41	0.39	0.34
% TEAA/TAA	0.29	0.44	0.01	0.04	0.05	0.04	0.011	0.014
TEA without His	230	164.7	336	389.9	425.6	526	1149	743
TNEAA	40	19.6	1481.4	676.2	466.6	560.8	2060	1623
TArAA	86	70.1	139.3	140.8	160.1	203.5	537	261
TSAA	55.0	30.1	44.7	100.3	39.5	42.2	154	93
%TSAA	81.70	15.47	2.43	10.36	4.33	3.80	4.57	3.80

Leu/Ile	4.33	1.80	1.98	1.69	2.81	3.38	1.70	1.78
Leu-Ile	60	17.5	15.3	42.3	29.0	65.1	105	69
% Leu-Ile	20.41	9.02	0.831	4.37	3.18	5.87	3.11	2.82

Amino Acids Quality Parameters

In co fermentation of germinated maize with ungerminated cowpea: The calculated parameters from amino acids are shown in Table 3. TNEAA, TSAA, TarAA, TEAA/TAA leu/ile were all more concentrated in GM/CO than UGM/CO. The percentage ratios of TEAA/ TAA in both samples were significantly (p0<0.5) lower than the 39% adequate for protein food of infants. [FAO/WHO/UNU 1985, FAO/WHO, 1990]. The TSAA of 55mg/1gcp (GM/CO), was comparable to 58 mg/ g cp recommended for infants, while that of UGMCO of 15.4 (UGM/CO) was significantly (p<0.05) lower. But the TarAA range in both samples was close to the value 70.0 to 91.0 mg/g cp suggested for ideal infant protein (**Oyarekua, 2014**).

In the study on co-fermented cereals/cowpea: The percent ratio of essential amino acid to the total amino acid (TEAA/TAA) in Millet/Cowpea and Sorghum/Cowpea were well above 26 and 11% recommended by [FAO/WHO/UNU] (1990) for ideal protein food for infants (**Oyarekua 2010**). The values obtained for Sorghum/Cowpea and Millet/Cowpea were also significantly (p<0.05) lower to that of egg (50%) as recommended by [FAO/WHO/UNU] (1990).

In the study on cooked and raw walnut co-fermented with maize: The total amino acids were 1839 and 968.4 in RWM and CWM respectively. While total essential amino acids (TEAA) were higher in CWM than RWM this indicates that cooked walnut co-fermented with maize may enhance the TEAA of the mixture. The ArAA of RW/M 139.3 and CW/M 140.8 mg/g cp were lower than the range of 68-118mg/ g cp suggested for ideal infant protein. But percentage ratios of TEAA to TAA was lower in RWM while that of CWM was higher than 39% considered to be adequate for ideal protein food for infants (**Oyarekua** and Bankefa **2016**).

Summary of Quality Parameters

In all the samples I observed that cassava/cowpea/ carrot was more enhanced in TAA, TEAA with histidine, and TEAA without histidine, TNEAA, TArAA, TAA and TSAA.

Consistency

Consistency/Viscosity: It would appear that Nicol (1971) in Nigeria was the first to mention "dietary bulk" as a possible cause of protein-energy malnutrition in infants. It is necessary to increase the energy density of complementary foods based on locally produced staples because of children's limited gastric capacity. According to **Oyarekua (2012), t**his can be achieved by fermentation processing of foods in order to reduce the viscosity of gruel to a level that is acceptable to infants when the gruel is prepared with adequate concentrations of dry matter. The viscosity measurement using Rotary Viscometer HAAKE model is expressed as Pascal value (p.a.s-1). The recommended viscosity of complementary food is in the range of 1-3(Pascal) p.a.s-1. Less than 1p.a.s is drinkable gruel, 1 p.a.s and up to 3 p.a.s) is spoonable while greater than 3 p.a.s is thick gruel. The consistency measurement using Bostwick Consistometer is measured in millimeter per 30 seconds (mm/30sec). Flour concentration of 10% was considered ideal for infants' complementary foods of gruels with a Bostwick flow of 120 mm/30secs which corresponds to a consistency suitable for infants and young children (Vieu *et al.* 2001). Bostwick consistometer measurement is inversely proportional to viscosity measurement of Rotary Viscometer HAAKE Model.

The most ideal temperature of gruel for an infant's mouth is 45°C (**Oyarekua 2012).** In Nigeria, most mothers test this parameter by putting a drop of the gruel at the back of their palms before feeding the infant. Figs 6-9 shows consistency graphs.

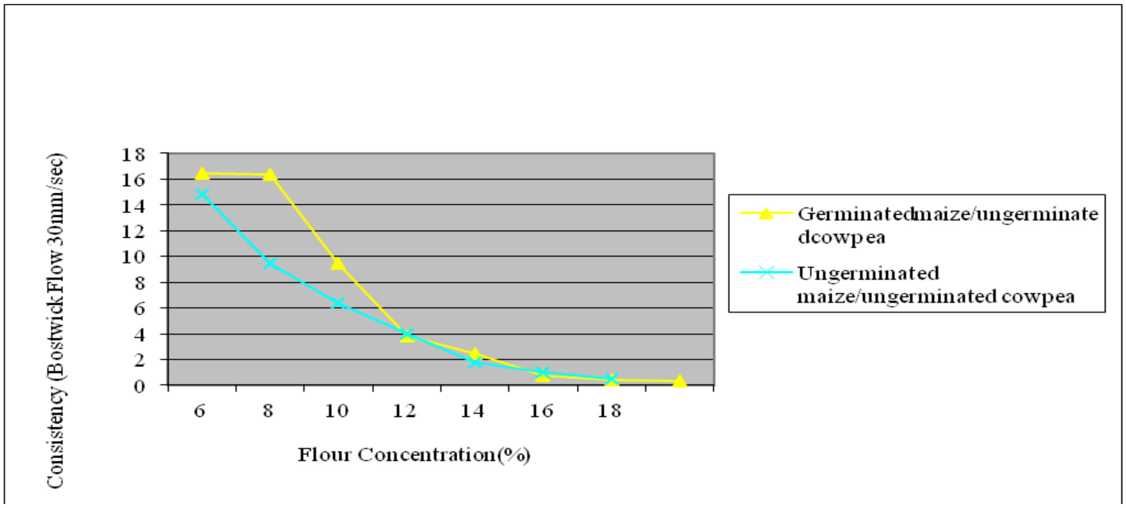

Fig 6: Effect of germination and co-fermentation on the consistency of Maize/cowpea

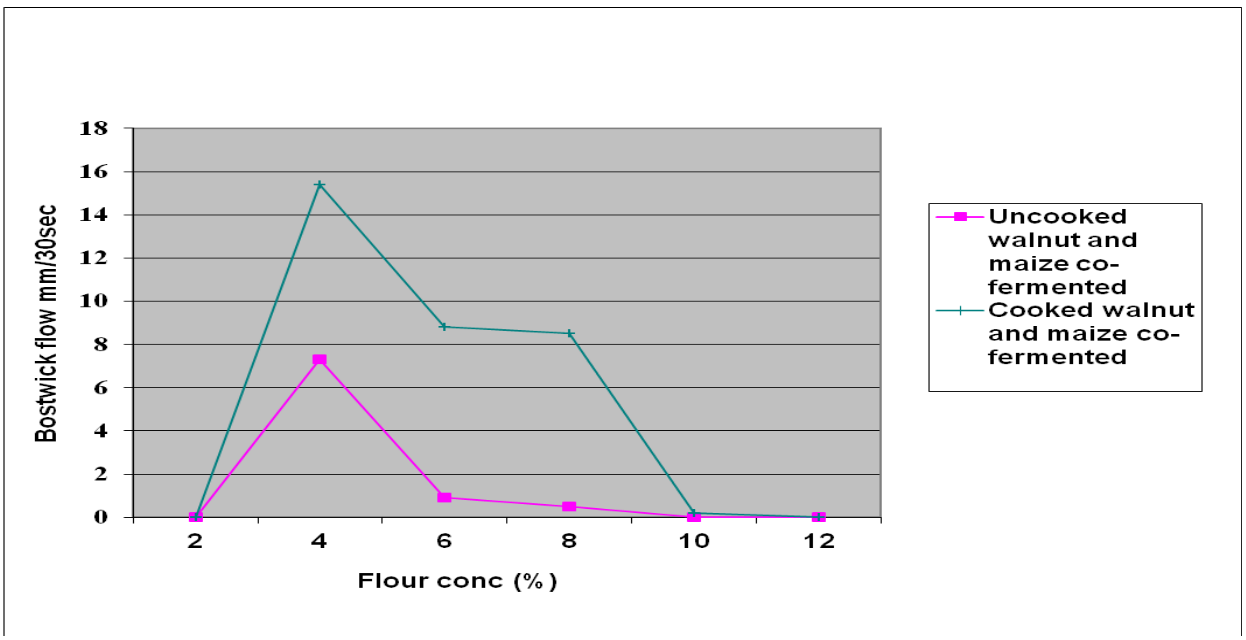

Fig. 7: Effect of cooking and fermentation on the consistency of co-fermented walnut and maize.

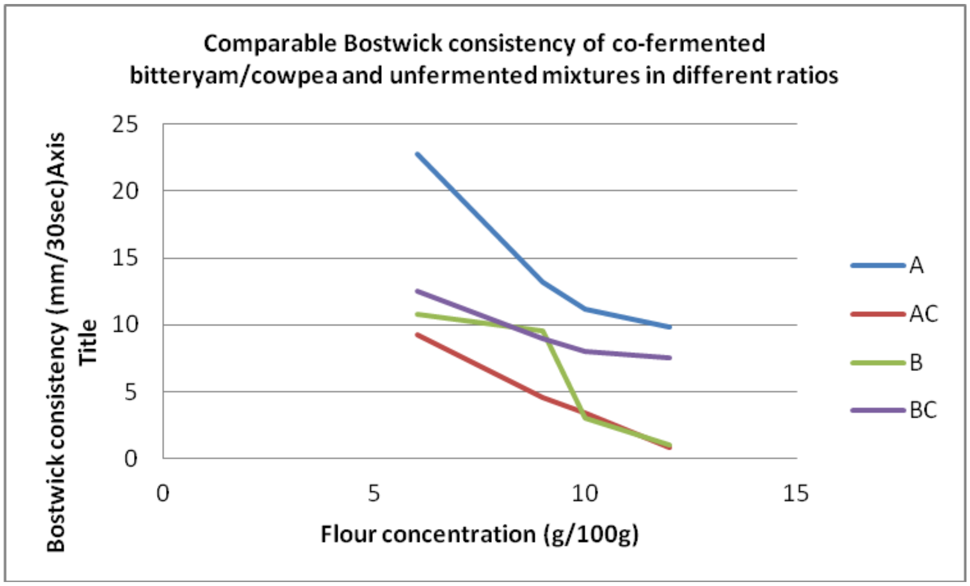

Fig 8: Comparable consistency of co-fermented bitter yam/cowpea and unfermented mixtures in different ratios.

A= Unfermented Bitter yam and cowpea 700:300, B= unfermented Bitter yam / cowpea 600:400g, AC= Bitter yam and cowpea 700:300, BC= Bitter yam / cowpea 600:400g.

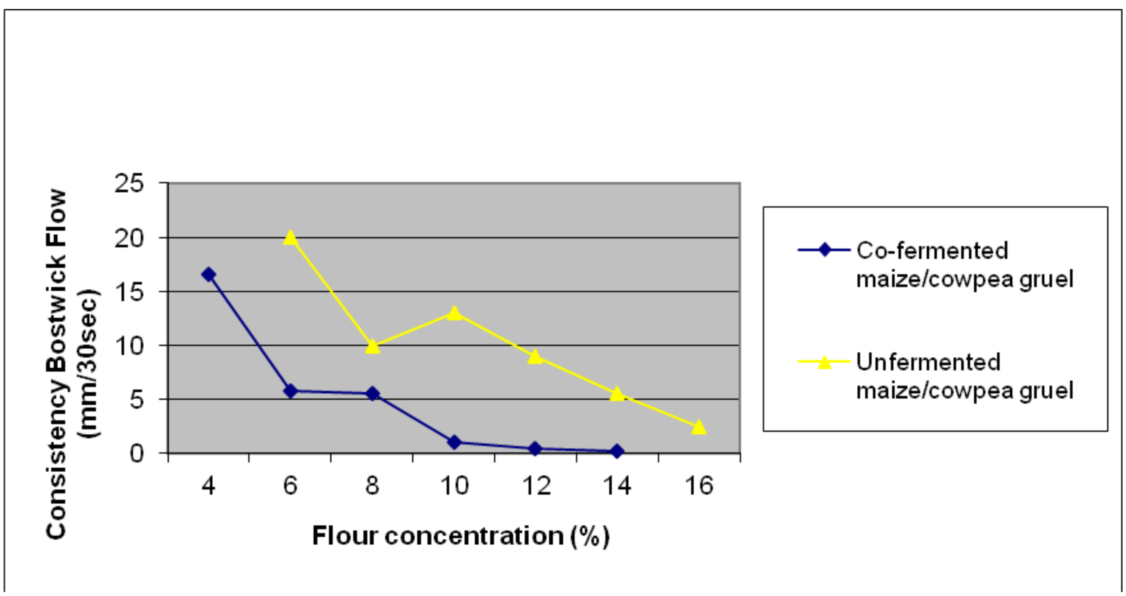

Fig 9: Consistency graph of co-fermented maize/cowpea gruel.

Consistency of co-fermented germinated maize and ungerminated cowpea: Figure 6, showed that there was significant ($p > 0.05$) increase in consistency of GM/CO. This might be due to starch degradation caused by amylase enzymes generated during germination process. Therefore, the gruel from GM/CO at 10% flour concentration might have the advantage in terms of reduced viscosity and increased nutrient densities (**Oyarekua 2012**); this finding is in agreement with the findings of Adams *et al*. (1989) who reported that germination reduced viscosity of barley.

Consistency of the gruel of co-fermented Walnut and Maize. In Fig7 at 6% and 8% CWM had higher consistency than RWM. **(Oyarekua** and Bankefa **2016).** At 10% both samples consistencies were too thick and could not be measured. The consistencies of the gruels at 10% might be due to interaction of cereals starches with protein which can influence gelatinization and retro gradation of starches **(Oyarekua 2016).**

Content of Co-fermented Bitter Yam/Cowpea Mixture in Different Ratio and their Unfermented Analogues

In Figure 8, at 10% flour concentration, co-fermented mixture of 600:400 had higher consistency (reduced viscosity) value than that of 700:300 ratios. This shows that co-fermented mixture of 600:400 gruel at 10% might be easy for the infant to swallow and might contain more nutrient and energy densities **(Oyarekua 2012).**

In co-fermentation on the viscosity of cereals/cowpea-cooked gruel using the Rotary viscometer HAKEES model: The consistency values of millet/cowpea were significantly higher than that of sorghum/cowpea as shown in Fig 9. However at 10%, sorghum/cowpea was too viscous to be read while millet/cowpea was 1.06p.a.s-1. Therefore, millet/cowpea flour concentration of 10% might have adequate nutrient density. Generally, I also observed that as gruel cools, the gruel consistency decreased irrespective of the concentration. This shows that infant must be fed when the gruel is still warm (45^{o}C) so as to maintain the right gruel consistency.

SENSORY EVALUATION

Sensory evaluation is a subjective measurement since it is subject to human errors. The other evaluations are called objective measurements, which involve physical, chemical and microbiological evaluations. The results of these objective measurements must be correlated with the results of sensory evaluation so that acceptability of the food by the ultimate consumer can be correctly ascertained **(Oyarekua 2008)**. For sensory evaluation results to be meaningful, they must be interpreted statistically. The results of all my products were statistically analyzed at 1% level by analysis of Variance (ANOVA), **(Oyarekua 2008)**.

Table 5: Sensory parameters of co-fermented samples

Sample	Colour	Texture	Taste	Aroma	Acceptability
Co-fermented maize/cowpea	7.5	7.6	8.0	7.2	8.5
Co-fermented millet/cowpea	6.5	6.4	6.4	5.6	7.0
Co-fermented sorghum/cowpea	4.6	5.4	5.2	5.7	5.8
Co-fermented bitter yam/cowpea 700:300	4.40[a]	6.10[a]	4.11[a]	3.90[b]	6.10[a]
Co-fermented bitter yam/cowpea 600:400	4.40[a]	6.70[b]	4.90[b]	3.50[a]	6.11[a]
Unfermented bitter yam/cowpea 700:300	5.11[b]	7.40[c]	6.70[c]	5.90[c]	4.10[b]
Unfermented bitter yam/cowpea 600:400	5.10[b]	7.40[c]	6.80[d]	5.90[d]	4.12[b]

Values are in duplicates. Values with the same superscript are significantly comparable with each other.

Sensory evaluation of co-fermented millet/cowpea, sorghum/cowpea and maize/cowpea as infant complementary food:

Colour/appearance: The cooked gruel of maize/cowpea and millet/cowpea showed similar scores in terms of colour while sorghum/cowpea scored the least.

Texture: Maize/cowpea scored higher in preferred texture than others.

Taste: maize/cowpea '*ogi'* score was more preferred in taste than sorghum/cowpea and millet/cowpea had more radish taste.

Aroma: The aroma of maize/cowpea was preferred and scored higher than millet/cowpea and sorghum/cowpea.

As seen in Table 5, among the gruels of co-fermented mixtures, maize/cowpea scored higher values in colour, texture, taste, aroma and general acceptability. The difference between the rating of the three products might be mainly because maize '*ogi;* is the familiar product to the panelists. Therefore this might have played an integral part in the panelist's response to maize/cowpea '*ogi'* which was a new product **(Oyarekua 2008**). Therefore the judgment of the new product was largely based on comparison with maize '*ogi'* that the consumers had been used to. If maize/cowpea '*ogi'* is cooked longer than 10 minutes, the taste might be acceptable **(Oyarekua 2016).** However the rating of maize/cowpea is still higher than any of the three products.

In Sensory Evaluation of Bitter Yam and Cowpea as Complementary Food.

The best result of overall acceptability was found in both co-fermented samples with comparable values of 6.10 and 6.11 respectively. Also, these co-fermented samples were comparable in respect of colour, texture, taste and aroma as seen in Table 5**.** Generally, Lactic acid bacteria influence the flavour of fermented foods in the production of acid with attendant lowering of pH, this results is increase in sourness. The sensory parameters results also showed that mothers prefer the fermented sample to unfermented sample in terms of general acceptability **(Oyarekua 2016).**

SUMMARY AND CONCLUSION

Mr Vice Chancellor Sir, I hereby present the summary of my contributions to knowledge.

In co-fermentation of cereals/ legumes: Sorghum/cowpea and millet /cowpea, both samples satisfy crude protein, TAA, ArAA, leucine, and histidine requirements for infants of 6-23 months on low, average and high breast milk intake. In comparative evaluation of maize/cowpea and sorghum/cowpea, the crude protein quality in sorghum/cowpea was found to be satisfactory and met the requirement for 6-23months old infant. Sorghum/cowpea had higher content of most of the amino acids and TEAA. Thus, co-fermented sorghum/cowpea is of better protein quality than maize/cowpea sample. In sensory evaluation, maize/cowpea was preferred by mothers.

In the use of starter cultures: *Lacobacillus plantarum* new strain A6 was the most effective in terms of improving chemical proximate composition and reducing viscosity. The viscosity increased with flour concentration up to 9% and A6 gave the best overall results. However, high cost of procurement and maintenance requirements of starter cultures may limit its utilization in Nigeria.

In the effect of co-fermenting germinated maize with ungerminated cowpea: My study showed that co-fermenting germinated maize with ungerminated cowpea may improve the nutritional quality, increase its consistency (reduced viscosity) thereby increasing the nutrients and energy densities of the product. Reduction of viscosity is an advantage in infant complementary food.

Co-fermented walnut/maize: When walnut was co-fermented with maize, the cooked walnut/maize had higher crude protein value, reduced viscosity and required values of linoleic acids than raw walnut/maize mixture. However, mixture with raw walnut was enhanced in all the minerals. My study established rich source of oil and moderate level of protein in walnut which can be used to boost the protein level in maize successfully as infant food. Co-fermenting walnut with maize can serve as infant complementary food of improved nutritional quality.

Co-fermentation of cassava/cowpea/carrot: This is a cassava based study. The co-fermented mixture enhanced total amino acids and reduced viscosity. Co-fermentation of cassava/cowpea/carrot gave values of improved nutritional quality than fermented cassava ogi. However, cassava ‘ogi’ had higher contents of all minerals.

Effect of co-fermentation on nutritional and sensory evaluation of bitter yam/ cowpea. The measured sensory quality characteristics of the co-fermented blends had higher scores in, aroma taste and texture than the unfermented analogue.

Co-fermentation generally reduced anti-nutritional factors in all the samples. Supplementation with mineral loaded foods and vitamins would only be necessary when these are apparently absent in formulated complementary foods so as not to overload nutrients as the infant is expected to still be breast feeding till age 24 months.

The co-fermentation process can easily be adaptable by low-socio economic mothers. Co-fermenting substrates in various ratios should be considered as an option in the development of infant complementary foods. The use of under –utilized cereals- based, legumes, tuber and vegetables as infant complementary foods can be of tremendous financial benefit (due to low cost of staples), to socio-economic mothers in Nigeria; if traditional women are encouraged with Nutrition Education programs, to use the hitherto under- utilized cereals, legumes, tuber and vegetables. Most of the products of my research might improve nutrient densities and meet micronutrient needs of infants of 6-23 months old.

CHALLENGES

1. Lack of facilities to explore genomic approach to unravel microbial interactions and metabolic activity in mixed cultures in fermenting media during food production.
2. The non- availability of genome sequences for several species that are of food importance.
3. Human trial needs to be carried out to study the bioavailability and utilization of nutrients consumed from the co-fermented products.
4. Food is often analyzed only for a limited number of pathogens and not for all those potentially present.
5. Packaging: In a number of instances, food can be contaminated due to unsafe packing in containers that were previously used for pesticide but were not adequately washed before being re-used.
6. Also, seeds intended for planting and which had been treated with fungicides are often sold to consumers.
7. Cereals have been harvested too soon after being treated with pesticide.

RECOMMENDATIONS

1. There should be adequate evaluation of traditional processing of infants complementary foods to assess the microbial quality and other contaminations.
2. There should be strict government basic infant food legislation that will be regularly upgraded.
3. Laboratories in Faculties of Agriculture of higher institutions should be upgraded to full food processing industries for production, quality control, packaging and distribution to consumers.
4. Research studies on nutrients bioavailability, utilization and fermentation genetics should be fully funded and encouraged.
5. There should be community based educational nutrition interventions by government. This should include nutritional counseling by verbal audio visual to provide adequate information to mothers on complementary foods and weaning practices.
6. There should be encouragement on intensive cultivation of underutilized staple varieties by the poor rural mothers and ensure that the products are affordable and can be eaten by infants, thereby reducing reliance on infant formula.

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REFERENCE

Achi, O. O. (2006).Traditional Fermented Food Condiments in Nigeria. *African J. of Biotechnology* 4 (13) Pp.1612-1621.

Adams, E. M, Drubin, D., and Bostein D.A. (1989).Yeast actin-binding protein is coded by Sac. 6- a gene found by suppression of an actin mutation. *Science* (243)Pp- 231-233.

Adeyeye E. I and **Oyarekua M. A. (2013).** Lipid Composition of three species of Solanum Consumed in Nigeria. .*Int. J. Chem. Sci.*6 (1) Pp 85-91.

Adeyeye, E. I. and **Oyarekua, M. A. (2008)**. Proximate Composition and Some nutritionally available Minerals in the Dehulled Seeds and Seeds Hull of *Anacaridium occidentale(L)* and *Blihia sapida (Koenig)-BioScience Biotechnology Research Asia* Vol. 5 (1) Pp.99-106.

Adeyeye, E. I., Orisakeye, O. T. and **Oyarekua, M. A. (2012).** Composition, Mineral Safety Index, calcium, Zinc and phytate interrelationships in Four Fast-Foods Consumed in Nigeria. *Bulletin of Chemical Society Ethiopia* 26(1):Pp. 001-012.

Agati, V., Guyot, J. P., Morlon-Guyot, J. Talamond, P. and Hounhouigan D. J. (1998). *Agriculture*.21,pp 619.

Akingbala J. O, Rooney L W, Faubion J.M. (1981). A laboratory procedure for the preparation of 'ogi'- a Nigerian fermented Food. *Journal of Food Science*, 43: 1523-1526.

CODESTAN:Codex Alimentarius Commission. (2006). Standard for infant formula and formulas for special medical purposes intended for infants. *Codex Stan* 72-1981.

CODEX, Codex Alimentarius Commission. (1991). Guidelines For Formulated Supplement For Older Adults And Young Children Adapted By Codex Alimentarius Commission At its 19^{th} Session 1991 CaC/CL8-1991.

Cohen R. J , Brown, K. H. Canahuati, J. Rivera, L .l. Dewey K. G. (1994).Effects of age of introduction of complementary foods on infant breast milk intake, total energy intake, and growth: a randomised intervention study in Honduras. *Lancet* 344(8918):288-93

Egounlety M. Aworh C.O., Akingbala J. O., Houber, J. H and Nago, C.M. (2002) Nutritional and Sensory Evaluation of Maize-Based Tempe Fortified Weaning Foods-*Int. J. of Food Science & Nutrition.* 53: PP15-27

Egli, I, Davidson, L., Juilerat, M. A, Barclay, D, and Hurell, F.R. (2003). Phytic acid degradation in complementary foods using phytase naturally occurring in whole grain cereals. *Journal of Food Science*, 68 1855-1859.

ESPGAN Working Group on Acute Diarrhoea. (1997). Recommendations for Feeding in ESPGAN. The European society of pediatric gastroenterology and nutrition (1994) committee on nutrition, exhibit significant potential health benefits, *Food Funct*. 3; 3(2), 134-140.

FAO/WHO (Food and Agricultural Organization/World Health Organization).1998. Preparation and use of Food-Based Dietary Guidelines. *Report of a Joint FAO/WHO Consultation. WHO Technical Report* series 880. Geneva.

FAO/WHO. (1997). Carbohydrates in Human Nutrition. In: International Report of a Joint

FAO/WHO/UNU. (1990). *Protein Quality Evaluation. In Report of Joint FAO/WHO*

FAO/WHO/UNU. (2007). Protein and Amino Acid Requirements in Human Nutrition http://whqlibdoc.who.int/trs/WHO_TRSZ_935Z_eng.pdf) page 150.

Fasasi, Eleyinmi , A. F. and **Oyarekua, M. A. (2007).** Effect of Some Traditional Processing Operations on the Functional Properties of African Bread Fruit Seed (*Treculia Aficana)* Flour. *L.W.T (Food Technology)* 40 (3) pp 513 – 519.

GAIN. Global Alliance for Improved Nutrition. (2018).

Giraud, E. Brauman, A., Keleke, S., Lelong, B., & Raimbault, M. (1991).Isolation and physiological Study of an amylolytic strain of *Lactobaccillus plantarum. Applied Microbiology and Biotechnology.* 36 (3), pp 379-383.

Hemalatha, S, Platel, K and Sriniavasan, K. (2007). Influence of germination and fermentation on bioaccessibikity of zinc and iron from food grains. *European journal of Clinical Nutrition* 61, pp342-348

Jansen, G. R.. (1980) A Consideration of Allowable Fibre Levels in Weaning Foods. *Food and Nut. Bull.* 2(4| Pp38-46

Livnyl O, Reifen, R, Levy, I, Madar, Z, Faulks, R., Southon S. & Schartz, B. (2003). β-carotene bioavailability from differently processed carrot meals in human ileostomy volunteeers. *Eur J. Nutr:* vol.42 (6) pp338-345}. www/springerlink.com/index/WY2M MVH8GXFDYP2Qpdf. Assessed 8th

Mouquet, C and Trèche, S. (2001). Viscosity of gruels for infants: A comparison of measurement procedures. *Inteniational Journal of Food Sciences and Nutrition (2001)* 52, 389-400.

Mouquet, C. (1998). Consistency of gruels for infants: a comparison of measurement procedures and the main influencing factor. *International conference of Ibadan, 16-21 November, 1998.*

Nicol, B. M. (1971). Protein and calorie concentration. *Nutrition Review*, 29 pp.83-88

Nigeria Food Consumption and Nutrition Survey) NFCN). (2004). (Summary)Eds. Maziya-Dixon, Nigerian sorghum porridge. *Journal of Cereal Science.* 1, 63. *Nutrition* 4 (3):pp.187-196.
Odunfa, S. S. Oyewole O.B. (2009).Effect of Lactic acid bacteria starter culture fermentation on cassava. *J of Applied Bacteriology* 68 /

(1) Pp.49-54.

Ojo O. I. **Oyarekua M. A,** and Jegede R .O. **(2018)** Trace Minerals, Physicochemical Composition of Locally Prepared Beverage (Kunu And Sobo) Commonly Consumed In Tertiary Institution Students In Ekiti-State, Nigeria. *International Journal of Chemistry* Vol.10 no.2 pp 80-84

Oladimeji O. and **Oyarekua M. A. (2017).** Nutritional Survey of Pre-School Children in Oriedo Local Government Area, Edo State, Nigeria. *International Journal of Nutrition and Food Sciences* vol 6 No: 6-1 Pp 26-33

Oyarekua M. A. & Bankefa O.B. (**2016**) The effect of cooking and fermentation on the functional and Nutritional properties of walnut and maize. *International Journal of Nutrition and Food Sciences* 4 (3)pp 332-342

Oyarekua, M. A. (2014). The effect of ungermibated cowpea on the nutritional quality of germinated maize. *International J. of Biotechnology and Food Science* vol 2(2) pp.35-43.

Oyarekua, M. A. (2008) Comparative Evaluation of the Nutritional Quality, Functional Properties and Amino Acid Profile of Co-fermented Maize/cowpea and Sorghum/Cowpea Ogi as Infant Complementary Food. *Asian Journal of Clinical Nutrition* 1 (1) 31-39

Oyarekua, M. A. (2016). Effect of Co Fermentation on Nutritional and Sensory Evaluation of Bitter Yam and Cowpea as Complementary Food. *International Journal of Current Microbiology and Applied Sciences.* ISSN: 2319-7692 (Print) ISSN: 2319-7706. Vol. 5 (4): PP 267-278.

Oyarekua, M. A, and Adeyeye E. I**. (2011).** The Amino Acid Profile of the Brain and Eyes of African giant pouch Rat (*Cricetomys gambianus*) *Agriculture and Biology Journal of North America* 2 (2): Pp.368-375. ISSN Print: 2151-7517.

Oyarekua, M. A. (2010). Effect of Fermentation on the Protein Digestibility and Antinutritional Factors of Co-fermented Maize/Cowpea Mixture. *International Journal of Chemical Sciences,* 5(1): 10-14. Nasarawa State University, Nigeria. Published by Nasarawa State University, Nigeria.

Oyarekua, M. A. (2011). Biochemical and Microbiological changes during the Production of Fermented Pigeon pea (Cajanus cajan) Flour. *African Journal of Food Science and Technology* (AJFST) 2 (10):Pp.223-231.

Oyarekua, M. A. (2016). Effect of fermentation on the Fatty Acids, Sterols and Phospholipids Content of Raw and Cooked Walnut for use as Complementary Food. *Nigerian Food Journal…*

Oyarekua, M. A. and Eleyinmi, A. F. **(2004)**. Comparative Evaluation of the Nutritional Quality of Corn, Sorghum and Millet 'Ogi' prepared by Modified traditional Technique. *Food Agriculture and Environment.* 2 (2):Pp.94-99.

Oyarekua, M. A. (2004). Effect of Co-fermentation on Total Phenol, Phytate and Minerals in Corn/Cowpea 'Ogi'. *Nigerian Academic Forum: A Multi disciplinary Journal*. 7 (2):Pp.122-129.Calabar, Nigeria. Published by University of Calabar.

Oyarekua, M. A., Akinyele I.O Treche, S. and Eleyinmi, A.F**. (2008).** Amyloytic Lactic Acid Bacteria Fermentation of Maize/Cowpea 'ogi'— *Int. Journal of Food Processing & Preservation* (32) pp.286-305.

Oyarekua, M. A. (2009). Co-Fermentation of Cassava/Cowpea/Carrot to produce Infant Complementary Food of Improved nutritive Quality. *Asian Journal of Clinical Nutrition* 1(3) Pp.120-130. (Pakistan).

Oyarekua, M. A. (2010) Evaluation of the nutritional and microbiological status of co-fermented cereals/cowpea 'ogi'.- *Agriculture and Biology .Journal of North America*. Vol 2(1):Pp.61-73.

Oyarekua, M. A. (2010) Sensory Evaluation, Nutritional Quality and Antinutritional Factors of Traditionally Co- fermented cereals /cowpea, Mixtures as Infant Complementary Food. -*Agric. Biol. J.N. Am.* 1 (5):Pp. 950-956.

Oyarekua, M. A. (2010) Evaluation of the nutritional and microbiological status of co-fermented cereals/cowpea 'ogi'.- *Agriculture and Biology .Journal of North America.* Vol 2(1):Pp.61-73. ISSN Print: 2151-7517.

Oyarekua, M. A. (2011) Evaluation of the nutritional and microbiological status of co-fermented cereals/cowpea 'Ogi'**.** *Agriculture and Biology Journal of North America* ISSN Print: 2151-7517, ISSN Online: 2151-7525, doi:10.5251/abjna.2011.2.1.61.73

Oyarekua, M. A. (2013). Comparative studies of co-fermented maize/pigeon pea and maize/mucuna as infants complementary foods. *Wudpecker Journal of Food Technology.* Vol.1 (1), pp-001-008

Oyarekua, M. A. (2013). Effect of Co-fermentation on Nutritive quality and pasting properties of Maize/cowpea/sweet potato as Complementary Food. *African Journal of Food, Agriculture, Nutrition and Development.* (AJFAND) Vol. 13. No1.Pp.7171-7191.

Oyarekua, M. A. (2013). Studies on the Nutritional Quality, Anti-nutritional Factors, Amino acid Profile and Functional Properties of Co-fermented Wheat/Cowpea. *Elixir Food Science* 54: Pp.12360-12364.

Oyarekua, M. A. (2014). The effect of ungerminated cowpea on the nutritional quality of germinated maize. *International Journal of Biotechnology and Food Science* Vol. 2(2), pp. 35-43.

Oyarekua, M. A . and Bankefa E. O. **(2015)**.The Effect of Cooking and Fermentation on the Functional and Nutritional Properties of Walnut and Maize. *International Journal of Nutrition and Food Sciences.* 4(3): pp.332-342.

Oyarekua, M. A and Ketiku, O. O. **(2010).** The Nutrient Composition of the African Rat. - *Advance Journal of Food Science and Technology* 2(6): Pp.318-324 (UK).

Oyarekua, M. A. (2012). Effect of Germination, Boiling and co-fermentation on the viscosity of maize/cowpea Mixture as Complementary Infant Food. *American Journal of Food Technology* 7 (1): Pp.1-12

Oyarekua, M. A. and Adeyeye, I. O. **(2009).** Comparative Evaluation of the Nutritional Quality, Functional Properties and Amino Acid Profile of Co-fermented Maize/Cowpea and Sorghum/Cowpea 'ogi' as Infant Complementary Food- *Asian Journal of Clinical Nutrition* 1 (1): Pp.31-39.

Oyarekua M. A, Ojo O. I., Ojo O. A. Adaramodu A.A **(2019)** Storage Effect On Microbial Load of Kunu Commomly Consumed By Tertiary Institution Students In Ekiti and Ondo States Under Various Preservative Regimes, *IOSR Journal of Science, Toxicology And Food Technology (IOSR-JESTFT) vol. 13, issue 12 ser*.1 pp19-25

Oyeleke, A. (1984). Outline of Food Analysis. *Ahmadu Bello University, Zaria Nigeria.* Pp 58.

PAG. (1971). Protein Advisory Group of the United Nations, PAG guideline no.8, protein-rich mixtures for use as weaning foods. New York: FAD/WHO/UNICEF.

Sefa-Dedeh, S.K.Y and Afoakwa 2001 .influence on fermentation and cowpea steaming on quality characteristics of maizecowpea blends. *Afri.J.Sci.Technol.*, 2 (2): 71-80.

Svanberg, U. (1987). Dietary Bulk in Weaning Foods and its Effect on Food and Energy intake: In: Alnwick, D., Moses S and Schmidt, O.G.eds. Improving young Child Feeding in eastern and Southern Africa. Nairobi, new York, Stockholm: IDRC, UNICEF, SIDA:272-287.

UNICEF. (2005). Nutrition: Complementary Feeding. available at: http://www.unicef.org/nutrition/index_24826.html 2005.

Vieu, M. C., Traore´, T., & Tre`che, S. (2001). Effects of energy density and sweetness of gruels on Burkinabe infant energy intakes in free living conditions. *International Journal of Food Sciences and Nutrition,* 52,213–218.

Vinson, J.A. and Cai, Y. (2012). Nuts, especially walnuts, have both antioxidant quantity and efficacy and exhibit significant potential health benefits. *Food Funct.* 3; 3 (2): 134 – 140.

WHO (1989) Protein Quality Evaluation Report of Joint FAO/WHO Technical Report Series 724 . WHO. Geneva.

World Health Organization. (1998). Complementary Feeding of Infants and Young Children. Report of a Technical Consultation Supported by WHO/UNICEF. University of California/Davies and ORSTOM. WHO, NUT/96-9.1998