SUDAN UNIVERSITYOF SCIENCEANDTECHNOLOGY

College of Graduate Studies

Production of Ready-to Serve Gluten Free Vegetables Based Infant Food

إِنْتَاج غذاءمن الخضر للأطفال الرُّضَّع جاهز للتقويمَ الِي مِنْ الجُلُوتِين

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بسم الله الرحمن الرحيم

قال تعالى:

وَهُوَ الَّذِيَ أَنزَلَ مِنَ السَّمَاء مَاء فَأَخْرَجْنَا بِهِ نَبَاتَ كُلِّ شَيْءٍ فَأَخْرَجْنَا مِنْهُ خَضِرًا
نُّخْرِجُ مِنْهُ حَبًّا مُّتَرَاكِبًا وَمِنَ النَّخْلِ مِن طَلْعِهَا قِنْوَانٌ دَانِيَةٌ وَجَنَّاتٍ مِّنْ أَعْنَابٍ
وَالزَّيْتُونَ وَالرُّمَّانَ مُشْتَبِهًا وَغَيْرَ مُتَشَابِهٍ انظُرُواْ إِلِى ثَمَرِهِ إِذَا أَثْمَرَ وَيَنْعِهِ إِنَّ فِي
ذَلِكُمْ لآيَاتٍ لِّقَوْمٍ يُؤْمِنُونَ ﭽ

سورة الأنعام الآية (99)

DEDICATION

In the name of ALLAH, the most merciful, the most compassionate.

To my:

Greatfamily, parents and husband, whom they stand

beside me, take care of me andsupport

me during this study.

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My thanks to **ALLAH**, who support me to take the decision to complete this study after being away from my profusion for around ten years.

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ABSTRACT

The main goal of this study was to develop aready-to-serve gluten free vegetables based infant food product with high nutritional value, high physico-chemical, microbial and organoleptic characteristics in order to contribute in solving the problem of children malnutrition in Sudan.

The results obtained in this study indicated that the developed vegetables based infant food product was found with high levels of available carbohydrates (68.32%), total sugars (12.75%) and protein (6.7%), but, with low levels of fiber (1.74%) and fat (1.02%), on wet basis. Also, the developed product was found to provide an adequate energy value (315.94 k.cal/100g) for infants and appreciable amounts of calcium (213.89 mg), potassium (140.79 mg), sodium (70.98 mg), phosphorus (49.89 mg), magnesium (28.02 mg) and vitamin-C (19.79 mg) per 100 gram food, on wet basis.

On the other hand, the total soluble solids (T.S.S %), hydrogen ions concentration (pH) and viscosity of the end product were found to be 22.93%, 6.47 and 788.63 centipoise, respectively. Moreover, the results of the microbial analysis revealed that, the product which was produced in this study as infant food was found safe according to the Gulf and Codex international standards for infants food. Finally, the product was highly accepted by the panelists (mothers) with respect to its colour, taste, odour, flavour, consistency and overall quality.

ملخص الدراسة

كان الهدف الأساسي لهذه الدراسة هو إنتاج غذاءمن الخضرللأطفال الرضع جاهز للإستخدام وخالي من الجلوتين و ذو قيمة غذائية عالية ويتميز بخواص جودة فيزيوكيميائيةو ميكروبية وحسية عالية، بهدف المساهمة في حل مشكلة سوء تغذية الأطفال في السودان.

أوضحت النتائج المتحصل عليها في هذه الدراسة أن المنتج الذي تم تحضيره من الخضروات للأطفال الرضع يحتوي على مستويات عالية من الكربوهيدرات المتاحة (68.32 %) و السكريات الكلية (12.75 %) والبروتين (6.7 %)، إلا أنه يحتوي على مستويات منخفضة من الألياف (1.74%) والدهون (1.02%)،على أساس الوزن الرطب. كما أن الغذاء المنتج يزود الأطفال الرضع بكمية كافية من الطاقة (315.94 سعر حراري / 100 جرام)، وكميات مقدرة من الكالسيوم (213.89) و البوتاسيوم (140.79ملجرام) و الصوديوم (70.98ملجرام) و الفسفور (49.89 ملجرام) و المغنسيوم (28.02 ملجرام) وفيتامين-C (19.79 ملجرام) لكل 100 جرام، على أساس الوزن الرطب.

ومن جهة أخرى، وجد أن نسبة الجوامد الصلبة الكلية الذائبه (T.S.S %) و تركيز أيون الهيدروجين (pH) ولزوجة المنتج النهائي كانت22.93 %، 6.47 و788.63 سينتيبواز (cp)على التوالي. بالإضافه إلى ذلك أكدت نتائج التحاليل الميكروبية سلامة المنتج الغذائي الذي تم إنتاجه في هذه الدراسه كغذاء للأطفال الرضع وفقا للمواصفات الخليجية واللجنة العالمية لدستور الغذاء.

وأخيراً وجد المنتج قبولاً عالياً من المحكمين (أمهات) من حيث خواصه المتعلقة باللون و الطعم والنكهة و الرائحة و القوام والجودة الكلية .

1. INTRODUCTION

Infant food is a food that primarily used during the infant period as a supplementary food. As breast feeding alone is not sufficient to meet the nutritional requirements of infants and young children after six (6) months of age **(WHO and UNICEF, 2011).**

In Sudan, the weaning food is widely varied due to regional differences in food supply, availability, food habits, traditions and feeding practices. In general, the main food groups in Sudan are cereals, fruits, vegetables and meat. However, thin porridge (Nasha), thick porridge (Aceda), blanched vegetables and fruits such as sweet potato, potato, carrot, cassava and banana are usually used as infants supplementary food during the weaning period **(Mohammed, 2004).**

The complementary foods are needed with the breast milk together to prevent infants and young children from severe and chronic malnutrition which are wide spread among children in Sudan. According to the UNICEF and WHO International Organizations, two (2) million Sudanese children under five (5) years old are actually malnourished and 550,000 of them are severely malnourished. In fact, 13% from all children suffering from severe malnutrition in Africa are located in Sudan **(WHO and UNICEF, 2011).**

The World Health Organization (WHO) estimates that malnutrition accounts for about 54 % of child mortality worldwide. Moreover, childhood underweight is considered as the main cause of death for about 35% of all death of children under five (5) years old worldwide. In fact, undernutrition in children was mentioned to cause direct structural damage to child brain and to impair infant development and exploratory behavior**.** Also, children with acute malnutrition were reported to be very thin, often with swollen hands, feet and often remain stunted for the rest of their lives even after recovering **(Duggan, 2013)**.

1.2 Objectives

1.2.1 Main objective

The main goal of this study is develop a well- blanched infant food from locally grown vegetables with high quality and nutritional value.

1.2.2 Specific objectives

(a) To determine the optimum processing method and conditions for production of vegetables based infant food.

(b) To study the chemical, physico-chemical and organoleptic characteristics of the end product .

(c) To help in reducing the level of infant malnutrition in Sudan.

(d) To encourage the local production of infants food from local vegetables raw materials at commercial level.

2. LETERATURE REVIEW

2.1 Infant Food

2.1.1 Definition

Infant foods are foods primarily used during the normal infant's weaning period. They may be either in ready-to-eat form or in dry form requiring reconstitution with water only. Other terms commonly used in this context are "solids", "weaning", "weaning foods", and "beikost". Any foods or liquids other than breast milk given to young children during the period of complementary feeding are defined as complementary foods. The term infant means a child not more than 12 months of age **(WHO, 2003).**

2.1.2 Weaning food practices and habits

Children's preferences for the majority of foods are strongly influenced by learning and experience; they develop a preference in relation to the frequency of exposure to particular tastes. The only innate preference is for the sweet taste, and even new born infants will avidly consume sweet substances, if given to them. Increasing the variety of foods will enhance a child's acceptance of different tastes. It is therefore important not to introduce sugar in any concentrated form (e.g. desserts, ice creams) until the infant has a chance to experience and develop a taste for other flavours, especially vegetables and fruits **(Birch, 1998).**

Children appear to consume more when they receive a varied diet compared with a limited monotonous one **(Gerrish and Mennella, 2001)**. It is important that children for whom all complementary foods are initially unfamiliar have repeated exposure to new foods during the early complementary feeding period in order to establish a healthy food acceptance pattern. It has been suggested that a minimum of 8–10 exposures are needed, with clear increases in food acceptance appearing after 12–15 exposures. Parents should thus be reassured that the rejection of new foods is normal. Foods should be offered repeatedly, as those that are initially rejected are often accepted later. If the child's initial rejection is interpreted as unchangeable, the food will probably not be offered to the child again and the opportunity for building up a broad range of exposure to and acceptance of new foods and tastes will be lost .The use of commercial complementary foods may delay the infant's acceptance of the family's normal diet and represents an unnecessary financial burden on family budgets (**Mennella, *et.al.*, 2001).**

Food for infant between 6-8 months should be given 2-3 times a day, increasing to 3-4 times daily after nine months of age. However breast milk should remain the primary source of nutrition for the whole of the first year of life **(Hernandez and Aguayo, 2005).**

As reported by **Northstone, *et.al.* (2001)**, most infant by around six months can sit with support and can "sweep a spoon" with their upper lip, rather than merely sucking semi-solid food off the spoon. By around eight months they have developed sufficient tongue flexibility to enable them to chew and swallow more solid lumpier foods in larger portions. From 9-12 months most infants have the manual skills to feed themselves, drink from a standard cup using two hands and eat food prepared for the rest of the family, with only minor adaptations. But, it is important for nutritional and developmental reasons, to give age-appropriate foods at the correct consistency and by the correct method.

According to **Mohammed (2004)**, the majority of the children in Sudan suffered from delayed supplementation. Only 37 % of the moderately malnourished and 28% of the severely malnourished children received supplementary feeding at the age of 14 months. Inadequate feeding practices during the weaning period caused a high mortality among infants and young children in the Sudan. Sudanese diet is based on cereal grain or root crops. Sorghum and wheat are the main staple foods, while millet constitutes the main staple in western Sudan and root crops such as cassava and yam are predominate in the South. The diversity in food production and the various ethnic groups in the different region of the country, each having their own food habits and traditions, have ultimately resulted in the consumption of varied types of diets. Weaning pattern in the country was found to vary widely due to regional differences in food supplies, availability and food habits. Weaned child in most parts of Sudan depends largely on adult traditional foods such as aceda and mullah. Milk is provided whenever it is available. Nevertheless, the major traditional weaning food used in Sudan was Nasha. It is a thin porridge made from sour sorghum flour usually containing not more than 10% dry mater with an energy density of about 20-30 kcal/100g .

According to the **WHO (2003)**, starting complementary infant feeding too soon is not advisable because:

(a) Breast milk can be displaced by other fluids or foods of poorer quality that may not be sufficiently nutritious and energy dense to meet the infant's requirements, and giving these foods or fluids can lead to a reduction in the mother's breast milk supply.

(b) Infants are not yet able to digest certain foods.

(c) The early exposure of infants to microbial pathogens potentially contaminating complementary foods and fluids puts them at increased risk of diarrheal disease and consequently malnutrition.

(d) The early exposure of infants to certain foods may trigger allergies.

(e) There is an earlier return to fertility for mothers, because decreased suckling reduces the period during which ovulation is suppressed.

On the other hand delaying the introduction of complementary foods for too long is also not advisable because:

(a) Breast milk alone may not provide enough energy and nutrients and may lead to growth faltering and malnutrition.

(b) Breast milk alone may not meet the infant's growing requirements of some micronutrients, especially iron and zinc.

(c) The optimal development of oral motor skills, such as the ability to chew, and the infant's ready acceptance of new tastes and textures may be adversely affected.

Infants should, therefore, be started on complementary foods at or shortly after six months of age.

Adding salt is not recommended when preparing complementary foods or family foods for infants and young children or indeed for any family members. Therefore, not adding salt in any food preparation will benefit the whole family. Very salty foods such as pickled vegetables, salted meats, stock cubes and soup powders should be avoided. If using salt, salty foods or spices for the rest of the family, a portion of family food should be removed for the infant or young child, prior to adding these. Sugar should not be added to foods for infants and young children either **(WHO, 2003).**

Baby food practices varies from culture to culture, in many cultures, grain pastes and liquids are the first baby food. An infant's first bite of solid food is ceremonial and holds religious importance in many cultures. An example of this is annaprashan. In India the infant is usually fed a sweetened rice porridge and blessed, by an elder family member. Similar rites of passage are practiced across Asia, including the Bengal region, Vietnam, and Thailand. A Hindu child receives its first solid food in a religious ceremony called Annaprashana . In the Western world until the mid-1900, baby food was generally made at home level **(Holmes, 2007).**

As mentioned by the **WHO and UNICEF (2011),** breast feeding alone is not sufficient to meet all the nutritional requirements of infants and young children after six months of age. There for complementary foods are generally needed after this age along with breast milk

2.1.3 Infant's food types

As indicated by the **WHO (2003),** transitional foods such as purée, mashed, semi-solid are foods specifically selected from the main food groups and adapted to meet the particular nutritional and physiological needs of the infant. While the family foods are largely based on a normal well-balanced varied family diet with some minor adaptations. Both transitional and family foods should be based on the family diet, if this is varied and well balanced sufficiently high in energy, protein and micronutrients, and adapted to the eating capabilities of a growing and developing infant. The change from breastfeeding alone to transitional foods and then to a normal family diet with the eventual cessation of breastfeeding, should be gradual. Therefore infant food is classified into two main types:

(a) Homemade infant's foods

According to **Ministry of Health (2006)**, many foods such as banana or cooked apple, can be prepared by pressing them through a domestic sieve with a wooden spoon. Fibrous components, for example, the stringy bits in taro leaves and Pele leaves, should be removed before processing. At a later stage, food needs only to be mashed with a fork. Salt, soy sauce, sugar, honey, cream, butter or margarine, or artificial sweeteners will not be added to infant foods.

The Department of Agriculture in the United States provides guidelines for safe preparation of baby food at home. Home-prepared spinach, beets, green beans, squash, and carrots should not be given to infants younger than six months of age because they may contain enough of a chemical (nitrates) to cause a condition that reduces the amount of oxygen carried by the blood (methemoglobinemia). In addition, home-prepared foods should not be given as infant food if they contain large amounts of added salt and/or sugar **(Greer and Shannon, 2005; Kleinman and Greer, 2014).**

(b) Commercial infant's foods

In developed countries, babies are now often started with commercially produced iron-fortified infant cereals, and then move on to mashed fruits and vegetables. Commercial infant's foods are widely available in dry, ready-to-feed and frozen forms, often in small batches (e.g. small jars) for convenience of preparation. Commercially prepared infants foods in the Netherlands were first prepared by Martinus van der Hagen through his NV Nutricia company in 1901. In United States they were first prepared by Harold Clapp who sold Clapp's baby food in the 1920s. The Fremont Canning Company, now called the Gerber Products Company, started in 1927. The Beech-Nut company entered the U.S. infants food market in 1931 .The first precooked dried infants food was Pablum which was originally made for sick children in the 1930s. Other commercial infant's food manufacturers include H. J. Heinz Company, Nestle, Nutricia and Organix. The demand from parents for organic food began to grow in the 1960. Since then, many larger commercial manufacturers have introduced organic lines of infant food .At the beginning of the 20th century in America, most babies began eating baby food around the age of seven months **(Bentley, 2006)**

According to **Bocquet, *et.al.* (2013)**, processed baby foods designed for infants which are referred to as baby foods, are specific products defined by a European regulation (Directive 2006/125/CE). According to this Directive, such foods have a composition adapted to the nutritional needs of children of this age and should comply with specifications related to food safety in terms of ingredients, production processes, and prevention of infectious and toxicological hazards.

2.2 Infant nutritional needs

2.2.1 Infant nutrients requirement

Posnick and Kim (2007) tabulated the nutrients requirements per pound of infant body weight in Table (1) which are proportionally higher than at any other time in their life cycle as they grow rapidly and must obtain an adequate amount of essential nutrients by consuming appropriate quantities and types of food.

2.2.2 Infants energy requirement

Lucas and Feucht (2003) mentioned that, infants need energy from food for their activities, growth and normal development. Energy usually comes from foods containing carbohydrate, protein or fat. The number of kilocalories (often termed “calories”) needed per unit of a person’s body weight is expressed as energy needs. However, an infant’s energy or caloric requirement depends on many factors, including body size and composition, metabolic rate, physical activity, size at birth, age, sex, genetic factors, energy intake, medical conditions, ambient temperature, and growth rate **(NCCDP and HP, 2007).** Tables (2) and (3) show the estimated energy requirements of infants based on the 2000 dietary reference intakes.

2.2.3 Energy intake and growth rate

As reported by **Butte, *et.al*. (2000)**, infant’s growth rates in length, weight, and head circumference are considered as general indicators of whether an infant is consuming an adequate number of kilocalories per day. In general, most healthy infants double their birth weight by 6 months of age and triple it by 12 months of age. However, keep in mind that there are normal differences in growth between healthy breastfed and formula-fed infants during the first year of life. **(Kleinman, 2007).**

Table (1): Infants nutritional requirements

Nutrient	**0-6 months / day**	**7-12 months / day**
Carbohydrates	60.00 g	95.00 g
Protein	9.10 g	11.00 g
Lipids	13.00 g	30.00 g
Fiber	0.00 mg	5.00 g
Vitamin-D	5ug(200 IU)	25ug(1,000 IU)
Vitamin-A	400.00 ug	600.00 ug
Vitamin-K	2.00 ug	2.50 ug
Vitamin-E	4.00 mg	5.00 mg
Vitamin-C	40.00 mg	50.00 mg

Niacin	2.00 mg	4.00 mg
Iron	0.27mg	11.00 mg
Sodium	-	200 mg
Phosphorus	-	400 mg
Potassium	-	700 mg

Source: Posnick and Kim (2007)

Table (2): Male infants estimated energy requirements

Age(month)	Reference weight (Kg)	Estimated energy requirements (Kcal/day)
1	4.4	472
2	5.3	567
3	6.0	572
4	6.7	548
5	7.3	596
6	7.9	645
7	8.4	668
8	8.9	710
9	9.3	746
10	9.7	793
11	10.0	817
12	10.3	844

Source: NCCDP and HP (2007)

Table (3): Female infants estimated energy requirements

Age (months)	Reference weight (Kg)	Estimated Energy Requirements (Kcal/day)
1	4.2	438
2	4.9	500
3	5.5	521
4	6.1	508
5	6.7	553
6	7.2	593
7	7.7	608
8	8.1	643
9	8.5	678
10	8.9	717
11	9.2	742
12	9.5	768

Source: NCCDP and HP (2007)

Ultimately, each infant's growth must be individually assessed. In addition to health and medical information, anthropometric data and biochemical data, the nutrition assessment of an infant should include an evaluation of breastfeeding frequency and duration, infant formula dilution and intake, appropriate amount and types of complementary foods and feeding skill development. Infants with abnormally slow or rapid growth rates or recent weight loss should be referred to a health care provider for assessment **(NCCDP and HP, 2007)**

2.2.4 Carbohydrates

Carbohydrates in the infant's diet are found to supply food energy for infant growth, body functions, and activity and allow protein and fat for normal uses in the body. The major type of carbohydrate normally consumed by young infants is lactose, the main carbohydrate source in breast milk and cow's milk-based infant formula. Lactose-free infant formulas, such as soy-based infant formulas, provide carbohydrates in the form of sucrose, corn syrup, or corn syrup solids. These infant formulas are prescribed to infants who cannot metabolize lactose or galactose, a component of lactose. Some specialty infant formulas contain other carbohydrates in the form of modified corn starch, tapioca dextrin, or tapioca starch. In later infancy, infants derive carbohydrates from additional sources including cereal and other grain products, fruits, and vegetables. Infants who consume sufficient breast milk or infant formula and appropriate complementary foods later in infancy will meet their dietary needs for carbohydrates **(NCCDP and HP, 2007).**

2.2.5 Protein

The essential amino acids include: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Two other amino acids, cysteine and tyrosine, are considered essential for the preterm and young term infant because enzyme activities involved in their synthesis are absent. However, breast milk and infant formulas provide sufficient protein to meet a young infant’s needs if consumed in amounts necessary to meet energy needs. In later infancy, sources of protein in addition to breast milk and infant formula include meat, poultry, fish, egg yolks, cheese, yogurt, legumes, cereals and other grain products **(IMFNB, 2005).**

2.2.6 Lipids

According to **Kleinman (2007)**, lipids in infants diet are consumed as a major source of energy to allow the absorption of the fat-soluble vitamins (A, D, E and K) and provide the essential fatty acids that required for normal brain development, healthy skin, hair, normal eye development and immunity. During infancy, breast milk and infant formula are important sources of lipids. The lipid content of breast milk varies, but after the first 2 weeks postpartum, breast milk as well as infant formulas provide approximately 50% of infant calories requirement.

Manufacturers of infant formulas add blends of vegetable oils which are high in linoleic essential fatty acid content. Food sources of lipids in the older infant’s diet other than breast milk and infant formula, include meats, cheese and other dairy products, egg yolks and any fats or oils added to home-prepared foods **(NCCDP and HP, 2007).**

2.2.7 Fiber

Dietary fiber is found in legumes, wholegrain foods, fruits and vegetables. Breast milk contains no dietary fiber, and infants generally consume no fiber in the first 6 months of life. It has been recommended that from 6 to 12 months whole-grain cereals, green vegetables and legumes be gradually introduced to provide 5 grams of fiber per day for infant of 1 year age **(Agostoni, *et.al.*, 1995)**

2.2.8 Cholesterol and fatty acids in infant diets

Cholesterol performs a variety of functions in the body but is not an essential nutrient because it is manufactured by the liver. Cholesterol is not added to infant formulas as breast milk contains a significant amount of cholesterol. A comprehensive analysis of 37 studies confirmed that total cholesterol was higher in breastfed infants than formula-fed infants **(Owen, *et.al.*, 2002).**

It has been suggested that breast milk's high level of cholesterol stimulates the development of enzymes necessary to prepare the infant's body to process cholesterol more efficiently in later life but carefully designed, well-controlled studies need to be conducted to confirm this possibility **(Lawrence, 2005)**

2.2.9 Vitamins and minerals

As reported by **NCCDP and HP (2007)**, infant's diet should not be fortified with vitamins or minerals during the first year of life unless they are prescribed by a health care provider. Excessive amounts of certain vitamins and minerals, in the form of drops or pills, can be toxic or even fatal to infants.

2.2.10 Water

The water requirements of healthy infants who are fed adequate amounts of breast milk or properly reconstituted infant formula are usually met by the breast milk or infant formula alone. The water was mentioned to regulated infant body, temperature, cell metabolism and kidney function **(Ziegler, 1990).**

2.3 Infant diet and risk of related autoimmune disorders

2.3.1 Celiac disease

According to the recommendations of the European Society for Pediatric Gastroenterology and Nutrition gluten-containing cereals should be introduced in the diet of European infants after the age of six months **(Elke and Fabio, 2000).**

Celiac disease is an immune-mediated enteropathy triggered by the ingestion of gluten in genetically susceptible individuals. Celiac disease is one of the most common lifelong disorders on a worldwide basis. The condition can manifest with a previously unsuspected range of clinical presentations, including the typical malabsorption syndrome (chronic diarrhea, weight loss, abdominal distention) and a spectrum of symptoms potentially affecting any organ or body system. Since celiac disease is often atypical or even silent on clinical grounds, many cases remain undiagnosed leading to the risk of long-term complications such as osteoporosis, infertility or cancer **(Fasano and Catassi, 2001).** Although celiac disease can present at any age, including the elderly, typical cases often manifest in early childhood **(Hervonen, *et. al.*, 2002).**

In Sweden an "epidemic" of early-onset celiac disease took place during the late 1980s and early 1990s. A retrospective analysis of this Swedish epidemic showed that the risk of celiac disease was reduced in infants introduced to gluten when still breastfed or who continued to be breastfed after gluten introduction **(Ivarsson, *et. al*., 2002).**

Some studies suggest that the pattern of infant nutrition may have a critical role on the development of celiac disease and other autoimmune disorders. Breastfeeding is thought to delay or reduce the risk of developing celiac disease. The positive effects of breast milk can be attributed at least in part to its influence on the microbial colonization process of the newborn intestine. The relationship between age at gluten introduction and the risk of celiac disease is still controversial **(Akobeng, *et.al.*, 2006).**

2.3.1.1 Clinical spectrum

As mentioned by **Fasano and Catassi (2001),** the typical form of celiac disease in children is characterized by gastrointestinal manifestations starting between 6 and 24 months of age after introduction of gluten in their diets. Infants and young children present with impaired growth, chronic diarrhea, abdominal distention, muscle wasting and hypotonia, poor appetite and unhappy behavior. Within weeks to months of starting to ingest gluten, weight gain velocity decreases and finally weight loss can be observed. A celiac crisis is characterized by explosive watery diarrhea, marked abdominal distension, dehydration, electrolyte imbalance, hypotension and lethargy. The symptoms may be intestinal or extraintestinal, the intestinal features may include recurrent abdominal pain, dental enamel defects, recurrent aphthous stomatitis and constipation. Between 6 and 12% of patients with iron-deficiency anemia attending a hematology clinic are found to have celiac disease. Celiac disease is the most common organic cause of slow growth rate and is much more common than growth hormone deficiency.

2.4 Nutritional value of vegetables as infants' raw food materials

Vegetables are considered as a rich source of vitamins, minerals, starch and fiber. Eating vegetables that contain vitamin-C along with iron rich foods will improve the absorption of non-heme iron from plant foods. Other micronutrients present in vegetables are B vitamins, including vitamin-B6. Dark-green leaves and orange-colored vegetables are rich in carotenoids which are converted to vitamin-A, while dark-green leaves are also rich in folate with potassium and magnesium present in significant levels. It is therefore, advisable to choose a variety of vegetables to meet daily nutrient recommendations. Some of the health benefits associated with vegetables consumption may come from non-nutrient components such as antioxidants and phytosterols. Most of vegetables require cooking for the improvement of digestibility and palatability. However, the deficiencies of iron, zinc, riboflavin, vitamin B12, vitamin D and calcium are highest in those with increased requirements, such as infants, children, pregnant and lactating women **(WHO, 2003).**

In Sudan various vegetables are grown in both irrigated and rain-fed plots. The most important vegetables are onion, tomatoes, potatoes, okra, eggplant and a number of leafy vegetables. Other vegetables like carrot, cabbage, red beet and cauliflower are grown at the outskirts of the large cities **(MOAF, 2005)**

2.4.1 Potato

Potato (*Solanum tuberosum L.*) is best known for its carbohydrate content (approximately 26 grams in a medium size potato tuber). The predominant form of this carbohydrate is starch. A small but significant portion of this starch is resistant to digestion by enzymes in the stomach and small intestine. This resistant starch is considered to have similar physiological effects and health benefits as fiber. It provides bulk, offers protection against colon cancer, improves glucose tolerance and insulin sensitivity, lowers plasma cholesterol and triglyceride concentrations, increases satiety and possibly even reduces fat storage. The amount of resistant starch in potatoes depends much on preparation methods. Cooking and then cooling potatoes significantly increases resistant starch. For example, cooked potato starch contains about 7% resistant starch, which increases to about 13% upon cooling **(Englyst, *et.al.*, 1992**, **Hylla, *et.al.*, 1998).** The storage and cooking method used can significantly affect the nutrient availability of the potato **(Tudela, *et.al.*, 2002; Madiwale, *et.al.*, 2012).**

Potatoes are often broadly classified as high glycemic index (GI) and so are often excluded from the diets of individuals trying to follow a low-GI diet. In fact, the GI of potatoes can vary considerably depending on type, origin, preparation methods , and with what it is consumed **(Fernandes, *et.al.*, 2005)**

Potato is a starchy tuberous crop which contains vitamins, minerals, phytochemicals such as carotenoids and natural phenols. Chlorogenic acid constitutes up to 90% of the potato tuber natural phenols. A medium-size 150 g (5.3 oz) potato with the skin provides 27 mg of vitamin C (45% of the Daily Value

(DV)), 620 mg of potassium (18% of DV), 0.2 mg vitamin B6 (10% of DV) and trace amounts of thiamin, riboflavin, folate, niacin, magnesium, phosphorus, iron and zinc **(Bohl and Johnson, 2010)**.

2.4.2 Sweet potato

The sweet potato (*kumara orbambai*) is a dicotyledonous plant that belongs to the family *Convolvulaceae* and it is a root vegetable. Besides, raw sweet potatoe is very rich in complex carbohydrates, dietary fiber and beta-carotene (a provitamin-A carotenoid), and it has moderate content of other micronutrients, including vitamin-B5, vitamin-B6 and manganese. The nutritional value of sweet potatoes has been ranked as highest among several other foods. Sweet potato varieties with dark orange flesh have more beta-carotene than those with light-colored flesh, and their increased cultivation is being encouraged in Africa where vitamin-A deficiency is a serious health problem. A study of 10,000 households in Uganda found that children eating beta-carotene enriched sweet potatoes suffered less vitamin-A deficiency than those not consuming as much beta-carotene **(Hartemink, *et.al.*, 2000)**

According to **DAF (2011),** there are two broad categories of sweet potato, the staple type with white flesh and white or purple skin with high starch and dry matter contents and the dessert type with orange flesh and skin with a high sugar and beta-carotene content.

2.4.3 Carrot

Carrots are usually made as purée and used as baby food or may be dehydrated to make chips, flakes, and powder, and thinly sliced and deep-fried, like potato chips **(Neil, 2006).**

The carrot (*Daucus carota* subsp. *sativus*) is a root vegetable usually orange in colour, though purple, black, red, white, and yellow varieties are existed. It has a crisp texture when fresh. The most commonly eaten part of a carrot is a taproot, although the greens are sometimes eaten as well. The carrot gets its characteristic, bright orange colour from β-carotene, and lesser amounts of α-carotene, γ-carotene, lutein and zeaxanthin. α- and β-carotenes are partly metabolized into vitamin A, providing more than 100% of the Daily Value (DV) per 100 g serving of carrots **(Abdel-Aal, *et.al.*, 2013) .**

Carrots are also a good source of vitamin K (13% DV) and vitamin B6 (11% DV), but otherwise have modest content of other essential nutrients. Carrots are 88% water, 4.7% sugar, 0.9% protein, 2.8% dietary fiber, 1% ash and 0.2% fat. Carrot dietary fiber comprises mostly cellulose, with smaller proportions of hemicellulose, lignin and starch. Free sugars in carrot include sucrose, glucose and fructose **(USDA, 2014).**

2.4.4 Legumes

In general, legumes are source of complex carbohydrates, proteins and dietary fiber having significant amounts of vitamins and minerals and high energetic value. Protein content in legumes grains range from 17% -40% contrasting with 7%-13% of cereals, and being equal to the protein content of meat 18%-20%. Nevertheless, the low nutritional value of legume protein represent one of the biggest problem **(Genovese and Lajolo, 2001).**

According to the United Nations Food and Agricultural Organization (FAO) and World Health Organization (WHO), proteins in cooked and germinated chickpeas are rich in essential amino acids such as lysine, isoleucine, tryptophan, and total aromatic amino acids **(El Adawy, 2002)**

A 100-g serving of cooked chickpeas provides 164 kilocalories (690 kJ). Carbohydrates make up 68% of calories, most of which (84%) is starch, followed by total sugars and dietary fiber **(El-Adawy, 2002; Bampidis and Christodoulou, 2011)**.

Infants and young children aged 6–24 months fed on vegan diets must be given a good variety of plant proteins; each meal should contain two complementary sources of plant protein, such as legumes accompanied by wheat or rice with lentils **(WHO, 2003).**

Legumes Lipid content is about 3%, 75% of which is unsaturated fatty acids for which linoleic acid comprises 43% of total fat **(USDA, 2014).**

2.5 The effect of processing on vegetable's chemical and physical characteristics

The range of textures that are encountered in fresh and cooked vegetables is indeed great, and to a large extent can be explained in terms of changes in specific cellular components. Since plants tissues generally contain more than two-thirds water, the relationships between these components and water further determine textural differences. When plant tissues are damaged or killed by storage, freezing, cooking, or other causes, an important major change that results is denaturation of the proteins of cell membranes resulting in the loss of perm-selectivity. The cement-like substance found especially in the middle lamella which helps hold plant cells to one another is a water-insoluble pectic substance. On mild hydrolysis it yields water-soluble pectin which can form gels or viscous colloidal suspensions with sugar and acid. Certain water-soluble pectic substances also react with metal ions, particularly calcium, to form water-insoluble salts such as calcium pectates. The various pectic substances may influence texture of vegetables and fruits in several ways. When vegetables are cooked, some of the water-insoluble pectic substance is hydrolysed into water-soluble pectin. This results in a degree of cell separation in the tissues and contributes to tenderness. Since many vegetables are somewhat acidic and contain sugars the soluble pectin also tends to form colloidal suspensions which will thicken the juice or pulp of these products. Vegetables also, contain a natural enzyme which can further hydrolyse pectin to the point where the pectin loses much of its gel forming property. This enzyme is known as pectin methyl esterase **(Dauthy, 1995).**

As mentioned by the previous author, the carotenoids are fairly resistant to heat, changes in pH, and water leaching since they are fat-soluble. However, they are very sensitive to oxidation, which results in both colour loss and destruction of vitamin A activity. The Flavonoids are water-soluble and commonly are present in the juices of vegetables. The flavonoids include the yellow anthoxanthins of light colored vegetables such as onion and potato. The yellow anthoxanthins are pH sensitive tending toward a deeper yellow in alkaline media. Thus potatoes become somewhat yellow when cooked in water with a pH of 8 or higher, which is common in many areas. Acidification of the water to pH (6) or lower favors a whiter color.

Dried chickpeas need a long cooking time (1–2 hours) but will easily fall apart when cooked longer. If soaked for 12–24 hours before use, cooking time can be shortened by around 30 minutes. Chickpeas can also be pressure cooked at 90°C (194 °F). Chickpeas are a nutrient-dense food, providing rich content (> 20% of the Daily Value, DV) of protein, dietary fiber, folate, and certain dietary minerals such as iron and phosphorus **(El-Adawy, 2002 and Jukanti, *et.al.*, 2012)** .

Cooking treatments do not lead to variance in total protein and carbohydrate content. Soaking and cooking of dry seeds possibly induces chemical modification of protein-fiber complexes which leads to an increase in crude fibre content. Thus, cooking can increase protein quality by inactivating or destroying heat-labile antinutritional factors. Cooking also increases protein digestibility, essential amino acid index and protein efficiency ratio. Although cooking lowers concentrations of amino acids such as tryptophan, lysine, total aromatic and sulphur-containing amino acids, their contents are still higher than the proposed by the FAO/WHO reference protein. Diffusion of reducing sugars, raffinose, sucrose and others into cooking water reduces or completely removes these components. Cooking also significantly reduces fat and mineral contents. The B vitamins riboflavin, thiamin, niacin and pyridoxine dissolve into cooking water at differing rates **(El-Adawy, 2002).**

Peeling is consider an inevitable treatment for rendering some vegetables more digestible but it may result in fairly heavy loss of some nutrient, especially of vitamins. Peeling before boiling increases the loss of ascorbic acid, folic acid or other vitamins of group B. Some of the important nutrients such as ascorbic acid and folic acid which are susceptible to oxidation are readily oxidized by brisk cooking. Minerals are also affected by high temperature, in some other cases flavor may be lost by brisk cooking. Excessive cooking may also cause an adverse effect on the digestibility of the vegetables **(Munir and Muhammad, 2003).**

Thiamin, vitamin-B6, magnesium and zinc contents are moderate, providing 10-16% of the DV. Chickpeas have a protein digestibility corrected amino acid score of about 0.76, which is higher than many other legumes and cereals **(Khatoon and Prakash, 2004)**

2.6 Infant food processing

In Sudan, chickpea and pigeon pea were used as protein sources, while dehydrated carrots powder was used as a source of vitamin-A for formulation weaning food. Addition of 25% chick pea or pigeon pea increased the protein content of the weaning foods to 16.7% and 14.4%, respectively. Incorporation of carrots at 10% level gave a vitamin-A content of 564 RE/100 g material. However, weaning food containing chick pea recorded the highest preference among the panelists and significantly better ($P<0.05$) than samples containing pigeon pea **(Omer, 1997).**

Weaning blends composed of 42% sorghum supplemented with 20% legumes, 10% oil seeds, and 28%additives (sugar oil, skim milk powder and vanillin).The blends were found to contain 16.6% to 19.3% protein, 68.7% to 72.7% carbohydrate, 0.9% to 1.3% fiber, and 405.8-413.2 kcal of energy per 100g. The iron and calcium contents in the blends ranged from 5.3 to 9.1 and 150 to 220 mg/100 g respectively. The water-holding capacity, wet ability, and bulk density were within the ranges of corresponding values of commercial weaning foods. Sensory attributes, viscosity values, and in-vitro digestibility varied among the blends, whereas lysing content improved considerably ($p \leq .05$) in all the blends. Also all the blends were found to have similar keeping quality **(Ali, *et.al.*, 2006).**

Twenty one food formulas included control were prepared as complementary babies food. Control was formulated mainly from papaya puree, potato, carrot, and skim milk powder with some fruit ingredients. These formulas were bottled in jars and thermal processed. The products were microbiologically safe and contained good amount of carbohydrates, carotenoids, anthocynin, ascorbic acid and minerals **(Bahlol, *et.al.*, 2008).**

Sorghum based infant food was produced by using cooking and drum drying methods. The product was made from decorticated sorghum flour, pigeon pea flour, milk, vit-C and other ingredients. The dried product was found to provide adequate amounts of protein (15.15%) and energy values (414.25 Kcal/100 g DM) and capable to meet the international standards for infants protein quality as recommended by the FAO/WHO/UNU (1985). The protein digestibility was found to be improved by cooking and drum drying. The produced sorghum-based infant food physical and functional properties tested showed that the product has low water retention capacity and low viscosity. When comparing the prepared sorghum-based infant food with some commercial infant foods available in the market, the product proved to provide more protein and energy value **(Abd-Elrahim, *et.al.*, 2011)**

In Nigeria, sweet potato puree was developed by **Cristina, *et.al.* (2011)** and used as weaning food. The cooking conditions were studied over temperature range of 80°C to 95°C so as to study their effects on the physio-chemical properties of the product. It was concluded that the optimum cooking temperature and time were 90°C and 7 min respectively for production of a high quality puree with 90 % color and 70% ascorbic acid retentions respectively.

Weaning foods were formulated from different blends of sorghum, soybean and unripe plantain flour using a commercial weaning food (Golden morn) as a control. The blend rational 80:10:10 sorghum: soybean: plantain flour were found to be the best while, the commercial weaning food had the highest preference by the panelists **(Nwakalor and Chioma, 2014).**

Samson (2014) formulated five formulas of baby food : (1) basal diet (100% Carbohydrate); (2) Vegetable based commercial diets; (3) Milk based commercial diets; (4) Corn flour (85%); and (5) Corn flour (85%), soy beans (15 %), sesame (5%), fortified with minerals and vitamins diet. The new baby food produced was tasted biologically by feeding it to experimental rats. The result showed these product could be applied to curb maternal morbidity and mortality in the developing countries.

2.7 Standards and specifications

2.7.1 Codex standards for canned baby food

According to the **Codex Standards Specifications (1989),** the following points should be considered:

2.7.1.1 Composition: Baby foods may be prepared from any suitable nutritive material that is used, recognized or commonly sold as an article or ingredient of food including spices. Vitamins and minerals may only be added in accordance with the legislation of the country in which the food is sold. Vitamins and/or minerals should be selected from the advisory lists of mineral, salts and vitamin compounds for use in foods for infants and children. The total sodium content of the products shall not exceed 200 mg Na/100 g calculated on the ready-to-eat basis in accordance with directions for use.

2.7.1.2 Consistency and particle size: Ready-to-eat baby foods are homogeneous or comminuted in the following forms:

(a) Strained: food of a fairly uniform, small particle size which does not require and does not encourage chewing before being swallowed.

(b) Junior: food that ordinarily contains particles of a size to encourage chewing by infants and children.

2.7.1.3 Specific prohibition: The product and its components shall not have been treated by ionizing radiation.

2.7.1.4 Food additives: Table (4) indicates the permitted food additives that could be used in preparation of canned baby food with some restrictions.

2.7.1.5 Contaminants

2.7.1.5.1 Pesticide residues: The product shall be prepared with special care under good manufacturing practices, so that residues of those pesticides which may be required in the production, storage or processing of the raw materials or the finished food ingredient do not remain, or, if technically unavoidable, are reduced to the maximum extent possible.

2.7.1.5.2 Other contaminants: The product shall be free from residues of horm- -ones and antibiotics as determined by means of agreed methods of analysis and practically free from other contaminants, especially pharmacologically active substances.

2.7.1.6 Hygiene: The product when tested by appropriate methods of sampling and examination should be:

(a) Free from any objectionable matter.

(b) Free from pathogenic microorganisms.

(c) Not contain any substances originating from microorganisms in amounts which may represent a hazard to health.

Table (4): Permitted food additives in canned baby food

Food additives	Maximum concentration levels (g/100g)
Thickening Agents Locust bean gum	1 0.2

Guar gum	0.2
Distarch phosphate	6 (single or in combination)
Acetylated distarch phosphate	6 (single or in combination)
Phosphated distarch phosphate	6 (single or in combination)
Hydroxypropyl starch	6 (single or in combination)
Acetylated distarch glycerol	6 (single or in combination)
Non-amidated pectin	1(in canned fruit-based baby foods only)
Emulsifiers	
Lecithin	0.5
Mono- and diglycerides	0.15
pH Adjusting Agents	
Sodium hydrogen carbonate Sodium carbonate Potassium hydrogen carbonate	Limited by good manufacturing practice and within the permitted limit for sodium.
Calcium carbonate	
Citric acid and sodium salt	0.5 and within the limit for sodium
L(+) Lactic acid	0.2
Acetic acid	0.5
Antioxidants	
Mixed tocopherols concentrate	300 mg/kg fat, singly or in combination ∝-Tocopherol
L-Ascorbyl palmitate	200 mg/kg fat
L-Ascorbic acid and its sodium	0.5 g/kg, expressed as ascorbic acid and potassium salts and within the limit for sodium
Flavors	
Vanilla extract	Limited by good manufacturing practice
Ethyl vanillin	7 mg
Vanillin	7 mg

Source: Codex (1989).

(d) Not contain any other poisonous or deleterious substances in amounts which may represent a hazard to health.

(e) Prepared, packed and held under sanitary conditions and should comply with the recommended international code of hygienic practice for foods for infants and children.

2.7.1.7 Packaging: The product shall be packed in containers which will safeguard the hygienic and other qualities of the food. If in ready-to-eat form, it shall be packed in hermetically sealed containers; nitrogen and carbon dioxide may be used as packing media.

2.7.1.8 Fill of container: In the case of products in ready-to-eat form, the fill of container shall be:

(a) Not less than 80% v/v for products weighing less than 150 g (5½ oz.);

(b) Not less than 85% v/v for products in the weight range 150-250 g (9 oz.); and

(c) Not less than 90% v/v for products weighing more than 250 g (9 oz.).

2.7.1.9 Labeling: In addition to the requirements of the Codex General Standard for the labelling of prepackaged foods **(Codex, 1985),** the following should be considered:

2.7.1.9.1 The name of the food: The name of the product shall be that of the major or characterizing ingredient(s) accompanied by words suitable to indicate the consistency or intended use.

2.7.1.9.2 List of ingredients: A complete list of ingredients should be declared on the label in descending order of proportion except that in the case of added vitamins and added minerals, these shall be arranged as separate groups for vitamins and minerals, respectively, and within these groups the vitamins and minerals need not be listed in descending order of proportion.

2.7.1.9.3 Declaration of nutritive value: The declaration of nutrition information shall contain the amount of energy, expressed in Calories (Kcal) and/or kilojoules (kJ), and the number of grammes of protein, carbohydrate and fat per 100 grammes of the food as sold as well as per specified quantity of the food as suggested for consumption; in addition to any other nutritional information required by national legislation, the total quantity in the final product of each vitamin and mineral should be added.

2.7.1.9.4 Date marking and storage instructions: The date of minimum durability (preceded by the words "best before") shall be declared by the day, month and year in uncoded numerical sequence except that for products with a shelf-life of more than three months, the month and year will suffice. The month may be indicated by letters in those countries where such use will not confuse the consumer. In the case of products requiring a declaration of month and year only, and the shelf-life of the product is valid to the end of a given year, the expression "end (stated year)" may be used as an alternative. In addition to the date, any special conditions for the storage of the food shall be indicated if the validity depends thereon. Where practicable, storage instructions shall be in close proximity to the date marking.

2.7.1.9.5 Information for utilization: Directions as to the preparation and use of the food and its storage and keeping before and after the container has been opened shall appear on the label or on the accompanying leaflet.

2.7.1.10 Advisory list of food additives for special nutrient forms:

The food additives included in the respective specific Codex standard that may be used for ready-to-use infant food and young children as mg/kg are shown in Table (5).However, some food additives may be used as nutrient carriers

2.7.2 Gulf standards for infants' food:

According to Standardization Organization for Gulf Standards **(GSO, 2014)** the acceptable total microbial count in infants food is (10^4- 10^2 cfu/g) and Salmonella is (0.0 cfu/g)

Table (5): Advisory list of food additives for ready-to-serve infant food and young children

Additive/Carrier	Maximum Level as(mg/kg)

Gum Arabic (gum acacia)	10
Silicon dioxide	10
Mannitol (for vitamin B12 dry rubbing, 0,1% only)	10
Starch sodium octenyl succinate	100
Sodium L-ascorbate (in coating of nutrient preparations containing polyunsaturated fatty acids)	75

Source: Codex (1989).

3. MATERIALS AND METHODS

3.1 Materials

Rice and fresh vegetables namely potato, sweet potato, carrot and chickpeas were purchased from Khartoum local market. All the samples were cleaned and kept in polyethylene bags and stored at 4°C until needed for the different investigations.

3.2 Methods

3.2.1 Chemical methods

3.2.1.1 Moisture content

The moisture content was determined according to the standard method of the Association of Official Analytical Chemists **(AOAC, 2003).**

Principle: The moisture content in a weighed sample is removed by heating the sample in an oven (under atmospheric pressure) at 105 °C. Then, the difference in weight before and after drying is calculated as a percentage from the initial weight.

Procedure: A sample of 5 gm ±1 mg was weighed into a pre-dried and tarred dish. Then, the sample was placed into an oven (No.03-822, FN 400, Turkey) at 105 ± 1 °C until a constant weight was obtained. After drying, the covered sample was transferred to desiccators and cooled to room temperature before reweighing. Triplicate results were obtained for each sample and the mean value was reported to two decimal points according to the following formula:

Calculation:

$$\text{Moisture content (\%)} = \frac{(W_s - W_d) \times 100\%}{\text{Sample weight (g)}}$$

[eq.1]

Where:

W_s = weight of sample before drying.

W_d = weight of sample after drying.

3.2.1.2 Crude protein content

The protein content was determined in all samples by micro-Kjeldahl method using a copper sulphate-sodium sulphate catalyst according to the official method of the **AOAC (2003).**

Principle: The method consists of sample oxidation and conversion of its nitrogen to ammonia, which reacts with excess amount of sulphuric acid forming ammonium sulphate. After that, the solution was made alkaline and the ammonia was distilled into a standard solution of boric acid (2%) to form the ammonia-boric acid complex which could be titrated against a standard solution of HC1 (0.1N).The protein content is calculated by multiplying the total N % by 6.25 as a conversion factor for protein.

Procedure: A sample of 10g±1 mg was accurately weighed and transferred together with 4g $NaSo_4$ of Kjeldahl catalysts (No. 0665, Scharlauchemie, Spain) and 25 m1 of concentrated sulphuric acid (No.0548111, HDWIC, India) into a Kjeldahl digestion flask. After that, the flask was placed into a Kjeldahl digestion unit (No.4071477, type KI 26, Gerhardt, Germany) for about 2 hours until a colourless digest was obtained and the flask was left to cool to room temperature.

The distillation of ammonia was carried out into 10m1 boric acid (2%) by using 20 ml sodium hydroxide solution (45%). Finally, the distillate was titrated with standard solution of HC1 (0.1N) in the presence of 2-3 drops of bromocreasol green and methyl red as an indicator until a brown reddish colour was observed.

Calculation:

$$\text{Crude protein (\%)} = \frac{(\text{ml HCl sample} - \text{ml HCl blank}) \times N \times 14.00 \times F \times 100\%}{\text{Sample weight (g)} \times 1000}$$

[eq.2]

Where:

N: normality of HCl.

F: protein conversion factor = 6.25

3.2.1.3 Fat content

Fat content was determined according to the official method of the **AOAC (2003).**

Principle: The method determines the substances which are soluble in petroleum ether (65-70 °C) and extractable under the specific conditions of Soxhlet extraction method. Then, the dried ether extract (fat content) is weighed and reported as a percentage based on the initial weight of the sample.

Procedure: A sample of 5gm ± lmg was weighed into an extraction thimble and covered with cotton that previously extracted with hexane (No.9-16-24/25-29-51, LOBA Cheme, India). Then, the sample and a pre-dried and weighed extraction flask containing about 100 ml hexanes were attached to the extraction unit (Electrothermal, England) and the extraction process was conducted for 6 hrs. At the end of the extraction period, the flask was disconnected from the unit and the solvent was redistilled. Later, the flask with the remaining crude ether extract was put in an oven at 105 °C for 3 hrs , cooled to room temperature in a desiccators, reweighed and the dried extract was registered as fat content according to the following formula;

Calculation:

$$\text{Fat content (\%)} = \frac{(W_2 - W_1) \times 100\ \%}{\text{Sample weight (g)}}$$

[eq.3]

Where;

W_2 =Weight of the flask and ether extract

W_1 =Weight of the empty flask

3.2.1.4 Total carbohydrates

Total carbohydrates were calculated by difference according to the following equation:

Total carbohydrates = 100% - (Moisture %+ Protein % + Fat % + Ash %).

[eq.4]

3.2.1.5 Crude fiber content

The crude fiber was determined according to the official method of the **AOAC (2003).**

Principle: The crude fiber is determined gravimetrically after the sample is being chemically digested in chemical solutions. The weight of the residue after ignition is then corrected for ash content and is considered as a crude fiber.

Procedure: About 2gm ± 1 mg of a defatted sample was placed into a conical flask containing 200m1 of H_2SO_4 (0.26 N). The flask was then, fitted to a condenser and allowed to boil for 30 minutes. At the end of the digestion period, the flask was removed and the digest was filtered (under vacuum) through a porclain filter crucible (No.3). After that, the precipitate was repeatedly rinsed with distilled boiled water followed by boiling in 200 ml NaOH (0.26 N) solution for 30 minutes under reflux condenser and the precipitate was filtered, rinsed with hot distilled water, 20m1 ethyl alcohol (96%) and 20 ml diethyl ether.

Finally, the crucible was dried at 105 °C (overnight) to a constant weight, cooled, weighed, a shed in a Muffle furnace (No.20. 301870, Carbolite, England) at 600 °C until a constant weight was obtained and the difference in weight was considered as crude fiber.

Calculation:

$$\text{Crude fiber (\%)} = \frac{(W_1 - W_2) \times 100\%}{\text{Sample weight (gm)}}$$

[eq.5]

Where:

W_1 = weight of sample before ignition (gm).
W_2 = weight of sample after ignition (gm).

3.2.1.6 Available carbohydrates

Available carbohydrates were calculated by difference according to the following equation:

(%) Available carbohydrates = Total carbohydrates (%) – Crude fiber (%)

[eq.6]

3.2.1.7 Total, reducing and non-reducing sugars

The total sugars as well as reducing and non-reducing sugars were determined according to Lane and Eynontitrimetric method as described by the Association of Official Analytical Chemists (**AOAC, 1984)**.

Principle: Reducing sugars in pure solution in plant materials after suitable pre-treatment (to remove interference substances) may be estimated by using copper sulphate as oxidizing agent in a standard Fehling's solution.

Sample preparation:

(A) Reducing sugars

A sample of 10 gm + 1 mg was weighted and transferred to 250 ml volumetric flask. 100 ml of distilled water was carefully added and then neutralized with NaOH (1.0 N) to a pH 7.5 – 8.0. Then, about 2 ml of standard lead acetate (NO. 23500, BDH, England) was added and the flask was shaked and left to stand for 10 min at room temperature. After that, 2 ml of potassium oxalate (22%) were added to remove the excess amount of lead acetate and the solution was made up to volume (250 ml) with distilled water and filtered.

(B) Total sugars

From the previous clear sample solution, 50 ml was pipetted into a 250 ml conical flask and 5gm citric acid and 50 ml distilled water were added slowly. Then, the mixture was gently boiled for 10 min to complete the inversion of sucrose and left to cool at room temperature. After that, the solution was transferred to 250 ml volumetric flask, neutralized with 20% NaOH solution in the presence of few drops of phenolphthalein (NO. 6606 J. T Baker, Holland) until the colour of the mixture disappeared and the sample was made up to volume before titration.

Procedure: A volume of 10 ml from the mixture of Fehling's (A) and (B) solutions was pipetted into 250 ml conical flask. Then, sufficient amount of the clarified sugars solution was added from a burette to reduce Fehling's solution in the conical flask. After that, the solution was boiled until a faint blue colour is obtained. Then, few drops of methylene blue indicator (S-d-FINE-CHEM

LIMITED) were added to Fehling's solution and titrated under boiling with sugars solution until brick-red colour of precipitate cuprous oxide was observed. Finally, the titre volume (sample-plank) was recorded and the amount of inverted sugars was obtained from Lane and Eynon Table. The total sugars, reducing and non-reducing sugars were calculated by using the following formulas:

Calculation:

$$\text{Total sugars (\%)} = \frac{\{\text{invert sugar (mg) x dilution factor}\}\text{x } 100\%}{\text{Titre x sample weight (g)} \times 1000}$$

[eq.7]

$$\text{Reducing sugars (\%)} = \frac{\{\text{invert sugar (mg) x dilution factor}\}\text{ x } 100\%}{\text{Titre x sample weight (g) x } 1000}$$

[eq.8]

$$\text{Non-reducing sugars (\%)} = \{\text{Total sugars (\%)} - \text{reducing sugars (\%)}$$

[eq.9]

3.2.1.8 Ascorbic acid (vitamin-C)

Vitamin C was determined by High Performance Liquid Chromatography (HPLC) as described by **Brause *et.al.* (2003).**

Procedure:

A. Preparation of test solutions: 10 g food was blended with sufficient water and the dilution factor was Record. 1 mg dithiothreitol was added for each 1 mL filtrate. The extract was mixed with 5% trichloroacetic acid solution then it was filtered through fluted 18.5 cm cellulose filter paper. The extract was allowed to stand for 2 hrs.

B. Determination: Instrumentation and software detector were set up to 254 nm. Flow rate was operated at 0.5 ml/min. water was run through the column for ca 30 min, followed by mobile phase for 1 hto equilibrate column. 50 L of each of the 5 calibration standards were injected. Then, the peak response (height or area) was measured.0.5µm of each test solution was injected.

Calculations: The concentration of vitamin C (mg/100 g or mg/100 mL) was interpolated directly from the calibration regression using automated data reduction software from a manually constructed calibration curve.

3.2.1.9 Ash content

The ash content in all samples was determined according to the official method of the **AOAC (2003).**

Principle: The inorganic materials which are varying in concentration and composition are customary determined as a residue after being ignited at a specified heat degree.

Procedure: A sample of 5g±1 mg was weighed into a pre-heated, cooled, weighed and tarred porcelain crucible and placed into a Muffle furnace (No.20. 301870, Carbolite, England) at 600 °C until a white gray ash was obtained. The crucible was transferred to a desiccator, allowed to cool to room temperature and weighed. After that, the ash content was calculated as a percentage based on the initial weight of the sample.

Calculation:

$$\text{Ash (\%)} = \frac{(W1) - (W2) \times 100\ \%}{\text{Sample weight (g)}}$$

[eq.11]

Where**:**

W1**=** weight of crucible + ash

W2=weight of empty crucible

3.2.1.10 Minerals content

Ten milliliters (10 ml) of HCL (2N) were added to the remaining ash sample and placed in a hot sand path for about 10-15 min. After that, the sample was diluted to 100 ml in a volumetric flask and filtered. The trace elements ferrous (Fe^{++}) and manganese (Mn^{++}) were determined according to **Perkin Elmer (1994)** by using Atomic Absorbance Spectroscopy (JENWAY 3110, UK). Sodium (Na) and potassium (K) were determined by using Flame Photometer (Model PEP7 JENWAY). While, calcium (Ca), magnesium (Mg), and phosphorus (P) were determined as described by **Chapman and Parratt (1961).**

3.2.1.11 Food caloric value

The energy value of infant food sample was calculated based on at water factors as indicated by **Leung (1968).**

Protein = 3.87 K. cal/g

Fat = 8.37K. cal/g

Carbohydrate = 4.12K. cal/g

K. cal = 4.184 kJ

3.2.2 Processing method of vegetables based infant food

Vegetables samples namely potato, sweet potato and carrot were cleaned, washed, sorted, peeled with a veggie peeler, and cut into small cubes. While, chickpeas sample was sorted, washed, soaked overnight (16 hours) in tap water at room temperature, peeled and ground. Then one kilogram from each sample was put together into cleaned stainless steel kettle containing 8.0 kg of water and the mix was blanched at 100°C for 15 min. After that, the blanched raw materials inside the kettle were quickly blended with an electrical mixer and finely sieved to remove the plant cells debris. Then, the blend was cooked at 100°C with 200 mg of ground rice until the desired consistency was achieved. The cooked vegetables puree was immediately hot filled in sterilized glass gars, tightly closed with screw lid, and sterilized at 100°C for 45 minute. Finally the end product was stored in a refrigerator at 4°C until needed for the different investigations. Fig (1) shows the processing method and conditions, while Table (6) shows the recipe and total yield of the end product.

3.2.3 Physico-chemical methods

3.2.3.1 Total soluble solids

The total soluble solids as percent (TSS %) in the different samples were measured as described by **Ranganna (2001).**

Principle: The index of refraction of a substance is a ratio of light velocity under vacuum to its velocity in the substance which is largely dependent on the composition, concentration and temperature of the sample.

Procedure: After the adjustment of the Hand-Refractometer (No.002603, BS-eclipse, UK) **with** distilled water, the sample was placed on the surface of the refractometer prism, the prism was closed and the reading was recorded to the nearest 0.01 as T.S.S %.

3.2.3.2 Hydrogen ions concentration

The Hydrogen ions concentration (pH) of the different samples was determined as described by **Ranganna (2001).**

Principle: The pH value of the different samples was measured with a pH-meter. After standardization of the pH-meter electrodes with buffer solutions, the reading of the sample is recorded as pH value.

Procedure: After standardization of the pH-meter (N0.478530, Hanna, India) with buffer solutions (pH 4.01 and 7.00), the electrode of the pH-meter was rinsed with distilled water, immersed in the sample and left to stand until a staple reading was achieved. All the readings were expressed as pH to the nearest 0.01-pH units.

3.2.3.3 Consistency

The apparent viscosity (consistency) was determined as described by **(Ahmed and Ramaswamy, 2006)**

Procedure: The apparent viscosity of the sample was determined by using a Brook field Synchroelectric Viscometer (HAAKE, W, Germany) with spindle NO.4 (20 rpm) and expressed as centi-poise units (CP).

3.2.4 Microbiological analysis

The total bacterial, yeasts, molds and *E.coli* counts in the end product were determined according to the **Gulf Standardization Organization (GSO, 2014).**

3.2.5 Organoleptic evaluation method

The vegetables based infant food sample were sensory evaluated by using 20

mothers as panelists. The samples were evaluated according to their taste, Oder, flavor, consistency, and overall quality using the following quality scales:
1= excellent, 2= very good, 3= good, 4= acceptable, 5= unacceptable **(Ranganna, 2001).**

3.2.5 Statistical analysis method

The results were subjected to Statistical Analysis System (SAS) by using One-Factor Analysis of Variance (ANOVA). The Mean values were also tested and separated by using Duncan's Multiple Range Test (DMRT) as described by **Steel, *et.al.* (1997).**

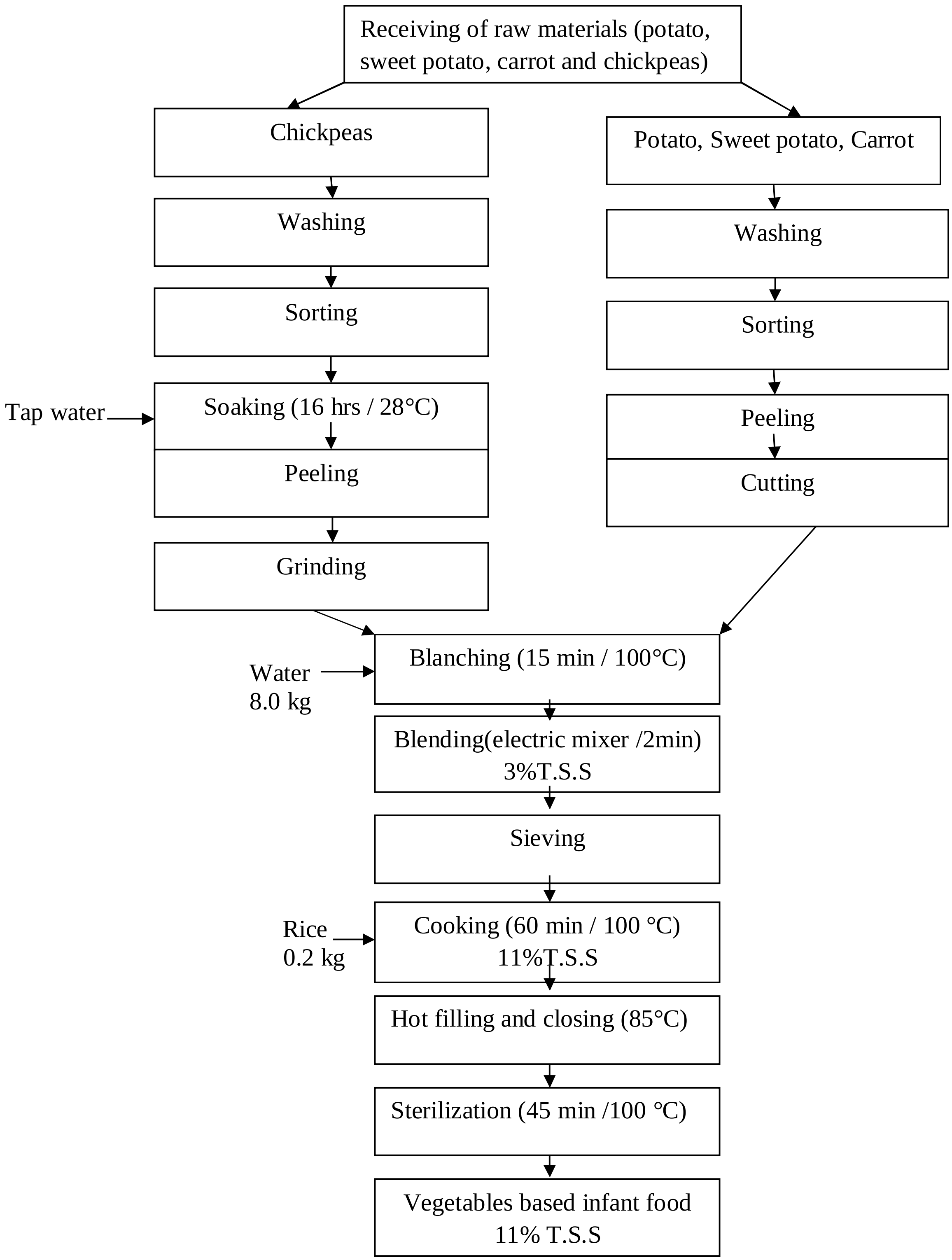
Receiving of raw materials (potato, sweet potato, carrot and chickpeas)
Chickpeas
Washing
Sorting
Tap water
Soaking (16 hrs / 28°C)
Peeling
Grinding
Potato, Sweet potato, Carrot
Washing
Sorting
Peeling
Cutting
Water
8.0 kg
Blanching (15 min / 100°C)
Blending(electric mixer /2min)
3%T.S.S
Sieving
Rice
0.2 kg
Cooking (60 min / 100 °C)
11%T.S.S
Hot filling and closing (85°C)
Sterilization (45 min /100 °C)
Vegetables based infant food
11% T.S.S

Fig (1) Processing method of vegetables based infant food

Table (6): Vegetables based infant food recipe and yield

Ingredients	(kg)	(%)
Potato	1.00	8.33
Sweet potato	1.00	8.33
Carrot	1.00	8.33
Chickpeas	1.00	8.33
Rice	0.20	1.67
Water	8.00	66.00
Total weight	12.200	100.00
Total yield	6.600	33 jar (200 gm)

4. RESULTS AND DISCUSSION

4.1 Suitable processing conditions of vegetables based infant food

After determination of the suitable method and processing conditions for production of vegetables based infant food, the cleaned peeled vegetables (4 kg) were blanched in pure water (8 kg) for 15 min at 100°C. After that, the mixture was blended for 5 min with an electric mixer and finely sieved. Then the blend was cooked at 100°C for 60 min with 200 g ground rice for production of vegetables based infant food. Fig (1) and Table (6) show the processing method and recipe which were used for production of vegetables based infant food.

4.2 Quality characteristic of the end product

4.2.1 Nutritional value of vegetables based infant food

4.2.1.1 Chemical composition and energy value

The chemical composition and energy value of the vegetables based infant food on wet and dry basis are shown in Table (7). From the results, the product was found to be with high level of available carbohydrates (68.32), total sugars (12.75%) and protein (6.7%), but, with low level of fiber (1.74%), fat (1.02%) and ash (0.87%) on wet basis. Therefore, the product could provide an adequate energy for infants (315.94 k.cal/100g) as the breast milk was mentioned to provide 50% of infants' energy requirement **(Kleinman, 2007).** The results obtained in this study are in good agreement with those recommended by **Posnick and Kim (2007).** However, the infants' energy requirements were mentioned to depend on many factors such as body weight, age, sex, genetic factors, physical activity, metabolic rate, ambient temperature and growth rate **(NCCDP and HP, 2007).**

Table (7): Chemical composition and energy value of vegetables based infant food

Chemical composition (%)	On wet basis	On dry basis
	(n = 3 ± SD)	
Moisture or Dry matter	21.35 ± 0.20	78.65 ±0.21
Protein	06.70 ±0.22	08.52 ± 0.26
Fat	01.02 ± 0.06	01.29 ± 0.06
Total carbohydrates	70.06 ± 0.27	89.08 ± 0.26
Crude fiber	01.74 ± 0.28	02.21 ± 0.35
Available carbohydrates	68.32 ± 0.47	86.87 ± 0.57
Total sugars	12.75± 0.10	16.21 ± 0.35
Reducing sugars	05.63±0.25	07.16 ± 0.33
Non-reducing sugars	07.12± 0.17	09.05 ± 0.22
Ash	00.87± 0.02	01.11 ± 0.01
Caloric value	315.94 ± 0.34 k.cal 1321.91 ± 0.87 k.J	401.67 ± 0.47 k.cal 1680.61± 0.97 k.J

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

4.2.1.2 Minerals and vitamins content

Table (8) gives the minerals and vitamin-C concentration in the end product as mg/100g on wet and dry basis. From the results, the product was found to provide appreciable amounts of calcium (213.89 mg), potassium (140.79 mg), sodium (70.98 mg), phosphorus (49.89 mg), magnesium (28.02 mg) and vitamin-C (19.79 mg) per 100 gram on wet basis. Therefore, this product could be considered as a good source of minerals and vit-C as infant's diet should not be fortified with minerals and vitamins during the first year of life unless they are prescribed by a health care provider. The excessive amounts of certain minerals and vitamins were mentioned to be toxic or even fatal to infants **(NCCP and HP, 2007)**

4.2.2 Physico-chemical characteristics

The physico-chemical characteristics of the vegetables based infant food has been recorded in Table (9). The total soluble solids (T.S.S), hydrogen ions concentration (pH) and viscosity of the end product were found to be 22.93%, 6.47 and 788.63 centipoise, respectively. The results obtained in this study are well agreed with the **Codex (1989)**

4.2.3 Microbiological characteristics

The total bacterial, yeasts, molds and *E.coli* counts in the end product are shown in Table (10). The results obtained revealed that, the vegetables based infant food product which was produced in this study is safe according to the **GSO (2014).** The acceptable total microbial counts should be ranged between $10^2 – 10^4$ (cfu/g) as stated by the **Gulf Standardization Organization (GSO, 2014).**

4.2.4 Organoleptic characteristics

The evaluation of the organoleptic characteristics of the vegetables based infant food was carried out by using 20 mothers. The results in Table (11) show the recorded scores by the panelists for the produced infant food with respect to its colour, taste, flavour, odour, consistency and overall quality. In general, the product was highly accepted by the panelists.

Table (8): Minerals and vitamins content of vegetables based infant food

Minerals content		**On wet basis**	**On dry basis.**
		Concentration (mg/100g) [n = 3 ± SD]	
Sodium	[Na]	70.98 ± 0.78	90.24 ± 0.99
Potassium	[K]	140.79 ± 1.07	179.01 ± 1.36
Calcium	[Ca]	213.89 ± 3.09	271.95 ± 0.02

Iron	[Fe]	02.44 ± 0.15	03.10 ± 0.00
Phosphorus	[P]	49.89 ± 1.09	63.43 ± 0.00
Magnesium	[M]	28.02 ± 0.37	35.63 ± 0.47
Zinc	[Zn]	00.11 ± 0.00	00.14 ± 0.01
Cadmium	[Cd]	00.00 ± 0.00	00.00 ± 0.00
Cobalt	[Co]	00.00 ± 0.00	00.00 ± 0.00
Copper	[Cu]	00.00 ± 0.00	00.00 ± 0.00
Vitamin –C		19.79 ± 0.08	25.16 ± 0.10

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

Table (9): Physico-chemical properties of vegetables based infant food

Parameter	**Mean value [n = 3 ± SD]**
Total soluble solids (T.S.S %)	22.93 ± 1.47
Hydrogen ions concentration (pH)	6.47 ± 0.14
Viscosity (Centipoises)	788.63 ± 10.39

SD ≡ Standard deviation

.

n ≡ Number of independent determinations.

Table (10) Microbiological evaluation of vegetables based infant food

Parameter	**Count (cfu/g) [n = 3 ± SD]**
Total bacterial count	< 2.1 ± 5.77

Yeasts and moulds count	< 2.1 ± 5.29
E.coli	0.00 ± 0.00

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

Table (11): Organoleptic characteristics of vegetables based infant food

[n = 20 ± SD]					
Colour	**Taste**	**Odour**	**Flavour**	**Consistency**	**Overall quality**
1.2±0.41	1.35±0.49	1.2±0.41	1.6±0.75	1.15±0.37	1.05±0.22

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

Scale: 1 = excellent, 2 = very good, 3 = good, 4 = acceptable, 5 = unacceptable

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the results obtained in this study it can be concluded that, vegetables such as potato, sweet potato, carrot and chickpeas are found to be more than suitable for production of infant's food with high quality and nutritional value. Also, the product was found to provide an adequate energy for infants and it contains appreciable amounts of calcium, potassium, sodium, phosphorus, magnesium and vitamin-C. Moreover, the product was found microbiologically safe and highly accepted by mothers.

5.2 Recommendations

(a) Production of vegetables based infant food should be encouraged specially for those Infants and young children suffering from lactose intolerance and celiac disease.

(b) Industrial utilization of locally grown food raw materials in production of Infants food should be encouraged to make these products affordable with low price to the low income groups in Sudan.

(c) Legumes which are rich in protein could be used in production of vegetables based infant food to avoid protein energy malnutrition (PEM) in developing countries.

(d) Further studies are definitely needed to determine amino acids and vitamins content as well as the optimum storage conditions, shelf life, packaging materials and economic feasibility of the end product.

(e) Production of infants food from locally grown vegetables will definitely make the product more popular and cheaper than imported infants food.

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Plate (1): vegetables based infant food Product

Plate (2): Sensory evaluation of vegetables based infant food