DEVELOPMENT OF A FOOD PRODUCT AS REPLACER FOR GEOPHAGY IN ADOLESCENT GIRLS: A CASE OF TWO SCHOOLS IN KAKAMEGA COUNTY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Sign…………………………… Date……………………………………

Judith Waswa - Admission number A80/91781/2013.

APPROVAL

This thesis has been submitted for examination with our approval as university supervisors.

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DEDICATION

I wish to dedicate this work to my husband Mr. Matti and children: Elvis, Ian and Noel.
ACKNOWLEDGEMENT

I wish to sincerely thank my supervisors Prof. Jasper K. Imungi and Dr Alice M. Mwangi whose assistance enabled me compete this thesis.

I also wish to thank the staff of UoN Food Science, Nutrition and Technology and Soil Science laboratories Department for enabling me develop my product by carrying out all the analysis. Not forgetting staff of Lumakanda District Hospital laboratory for enabling me do blood sample analysis. Special thanks to Mr Boniface Malingu for assisting in collection of blood samples from the participants and analysis. I also wish to extend my sincere gratitude to the institutions and girls who participated in the research for allowing me collect my data.

Special thanks go to my dear husband Mr Matti for his prayers, encouragement and financial support but not forgetting my young angels Elvis, Ian and Noel.
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<th>Description</th>
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<tbody>
<tr>
<td>MUAC</td>
<td>Mid Upper Arm Circumference</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for Social Scientists</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>Hb</td>
<td>Hemoglobin</td>
</tr>
<tr>
<td>Hct</td>
<td>Haemacrit</td>
</tr>
<tr>
<td>MVC</td>
<td>Mean Cell Volume</td>
</tr>
<tr>
<td>RBC</td>
<td>Red Blood Cell</td>
</tr>
<tr>
<td>SF</td>
<td>Serum Ferritin</td>
</tr>
<tr>
<td>C.I</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>ACC/SCN</td>
<td>Administrative Committee on Coordination/Subcommittee on Nutrition (United Nations)</td>
</tr>
<tr>
<td>AOAC</td>
<td>Association of Official Analytical Communities</td>
</tr>
<tr>
<td>XRF</td>
<td>X-Ray Fluorescence spectroscopy</td>
</tr>
<tr>
<td>AAS</td>
<td>Atomic Absorption Spectrometry</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
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DEFINITION OF TERMS

**Micronutrients** - The two classes of small non-energy yield elements and compounds, that is, vitamins and minerals, for example, zinc and iron.

**Pica** - The regular and deliberate eating of non-food substances such as soil, rock powder, chalk, ash, and other materials by humans.

**Geophagy** - A type of pica, which involves the consumption of soil or clay

**Phytates** - A plant's storage mechanism for phosphorus an anti-nutritional factor.

**Taste panel test** - Tasting of two or more samples of a meal and decisions made on the basis of comparison as to difference and preference

**Antinutrients** - Factors in foods that inhibit the absorption of nutrient from the food.

**Peroxide value** - Measure of rancidity in stored food.

**Tasters** - Panel members who are given meals to taste and give judgment in a taste panel test.
ABSTRACT

Geophagy is the regular and deliberate eating of soil by humans. It is common among pregnant women and children in sub-Saharan Africa.

Geophagy is often regarded as a response to compulsive physiologic demand including demand for iron and zinc in the body. However, geophagy significantly increases the risk of helminthes infestation. This study was designed to develop a food based geophagy replacer and assess its effects on geophagic practices and anemia status of adolescent girls in Western Kenya.

The study was organized in three phases. The first phase consisted of a baseline survey with a sample of 302 randomly drawn from two high schools in Likuyani Sub-County of Kakamega County. The study cohorts consisted of 154 girls from Moi girls Nangili and 148 from St. Annes’ Nzoia. The cohorts were proportionately drawn from forms one to four. A structured questionnaire was used to collect socio-demographic characteristics including geophagy. Anthropometric measurements of weight, height and mid upper arm circumference were taken using standard procedures. Blood and stool samples were taken to determine the hemoglobin status and presence of helminthes respectively. A seven day food record was taken and mean nutrient intakes computed.

Phase two consisted of laboratory development of an acceptable and shelf stable food replacer to contain adequate iron from millet, amaranth grains and termites.

Phase three of the study consisted of an intervention. The intervention study was done at St Annes’ Nzoia school after being randomly picked from the two schools that participated in the baseline survey. A sample of 58 cohorts was randomly drawn. The sample was split into two; the treatment group and the control group. Cohorts from both groups were given malaria prophylaxis and anti-helminthes treatment. The treatment group was further given the food replacer and requested to eat it as a drug and avoid sharing with friends. The cohorts
were given 30g of the food product per day for eight weeks. At the end of the intervention the girls were evaluated for geophagy and hemoglobin status.

Data were analyzed using Statistical Package for Social Scientist (SPSS) version 17. Mean, frequencies, Chi-square, t-test and multivariate logistic regression were used to analyze data. A nutrient calculator was used to analyze dietary data.

Results showed that the prevalence of geophagy was 46%. Significant predictors of geophagy were; being a daughter of a geophagic mothers and family size. The prevalence of anemia was 38%. Anemia was not found to be a predictor of geophagy. The meals of the cohorts did not provide adequate iron to meet the recommended Daily Allowance. The most preferred food replacer developed had ratio of 70:20:10 of (millet: amaranth: termites) and iron content of 16.6mg/100g. The replacer provided 4.98mg of iron per day (33% of RDA). Consumption of the soil replacer significantly reduced the geophagy practice by 96% and improved the hemoglobin status of the cohorts by 0.061g/dL. The study showed that an acceptable food replacer was suitable for reduction of geophagy in adolescent girls when well formulated with regard to iron content and would also improve the hemoglobin status of the cohorts.
CHAPTER ONE: INTRODUCTION

This chapter gives the background of the subject under investigation, the problem statement, justification, and objectives of the study.

1.1 Background

Geophagy is one of the types of pica, which involves consumption of soil, clay or rock powder. Pica is the regular and deliberate eating of non-food substances such as soil, rock powder, chalk, ash, and other materials by humans. It includes; amylophagy (consumption of starch), coprophagy (consumption of feces), mucophagia (consumption of mucus), pagophagia (consumption of ice), self-cannibalism (rare condition where body parts are consumed), trichophagia (consumption of hair or wool), urophagia (consumption of urine), xylophagia (consumption of wood), (Diamond, 1998)

Geophagy is common mainly among pregnant women and children in Sub-Saharan Africa. The practice is cultural and a widely accepted practice in African societies (Geislier et al., 1999). The prevalence of geophagy was reported to be 73.1% among children in Western Kenya (Geislier et al., 1998); 74.4% among Zambian girls (Nchito et al., 2004). A variety of soil types are consumed, including hardened clay soil (commonly found selling in shops and markets for the purpose) and soil from the walls of houses or termite mounds. Consumption of dust or sand has also been reported.

There are three major postulates that have been advanced to explain the physiological causes of geophagy: hunger, micronutrient deficiency, and protection from toxins and pathogens (Young et al., 2007).

The hunger hypothesis posits that people consume non-food substances because they do not have anything else to eat (Laufer, 1930).
The micronutrient deficiency hypothesis posits that people with micronutrient deficiencies eat non-food substances in an attempt to increase micronutrient intake of iron (Hunter, 1973) and Zinc (Smith and Halsted, 1970). Another version of this hypothesis is that a micronutrient deficiency causes disturbed taste sensitivities or malfunctioning of appetite-regulating brain enzymes that cause non-food substances to become appealing (von Bonsdorff, 1977). In this scenario, pica is a consequence of micronutrient deficiency, but not an attempt to remedy it.

The protection hypothesis postulates that geophagy is motivated by an attempt to mitigate the harmful effects of plant chemicals or microbes (Johns, 1986 and Profet, 1992). It is proposed that pica substances protect by binding pathogens or the toxins within the gut lumen or by coating the surface of the intestinal endothelium, thereby rendering it less permeable to toxins and pathogens. According to this hypothesis, overt gastrointestinal distress, which can be as a result of exposure to either toxins or pathogens (Simjee, 2007), also trigger pica. Additionally, this hypothesis implies that pica substances would be ingested during periods of rapid growth, i.e., the times of greatest need for protection from toxins and microbes. Under this hypothesis, childhood and pregnancy, especially early pregnancy [which is the critical period of organogenesis (Moore and Persaud, 1998)], are the periods when pica most likely would occur (Flaxman and Sherman, 2000).

A transitional period between childhood and adulthood, adolescence provides an opportunity to prepare for a healthy productive and reproductive life, and to prevent the onset of nutrition-related chronic diseases in adult life, while addressing adolescence-specific nutrition issues and possibly correcting some nutritional problems originating in the past (Barr et al., 1998).

Heavy menstrual blood loss may be an important factor in iron deficiency anaemia, as observed with study on Nigerian girls; it might also be related to vitamin A deficiency (Barr et al., 1998). Geophagy is also speculated to be a risk factor for helminth infestation as shown
in Figure 1.1. Helminth infestation is reported to affect over 1 billion people in tropical developing countries and contributes to severe morbidity (Antelman et al., 2000). People who practice geophagy are at high risk of infestation with *Ascaris lumbricoides* and *Trichuristrichiura* by ingesting eggs from contaminated soil. *Ascaris lumbricoides* and other intestinal helminthes may cause anemia (Antelman et al., 2000).

Although nutrient supplementation programmes have an immediate impact, they rely on external support for supply of supplements, which may make them difficult to sustain in the long term. Additionally, supplementation programmes frequently fail to reach the most needy cases of micronutrient deficiency. Food-based strategies also referred to as dietary modifications; encompass a wide variety of interventions that aim at: increasing the production, availability and access to food; increasing the consumption of foods rich in these micronutrients; and/or increasing the bioavailability of the micronutrients as shown in Figure 1.1.
Food-based strategies are considered sustainable because they involve empowerment of individuals and households to take ultimate responsibility over the quality of their diet through own-production of nutrient rich foods and informed consumption choices (Khakoni, 2009). These strategies are said to be “the ideal long-term goal toward which society strives provision of assurance of access to a nutritionally adequate diet achieved through diversity of food availability, wise consumer selection, proper preparation, and adequate feeding” (Khakoni, 2009). Food based strategies are also appealing because they can address multiple nutrients simultaneously without the risk of antagonistic nutrient interactions or overload. A
good, varied diet is the reason most of the world's population is free from micronutrient deficiency.

1.2 Theoretical Framework of Geophagy

Several theoretical approaches have attempted to explain the etiology of geophagy from nutritional, sensory, physiologic, neuropsychiatric, cultural, or psychosocial perspectives. Nutritional theories are most commonly cited, which attribute geophagy to specific deficiencies of minerals, such as iron and zinc. Many studies describe patients with low iron or zinc levels whose geophagy behavior diminishes with iron or zinc replacement (Abrahams, 1997). There has been a controversy regarding whether soil eating is nutritionally beneficial or harmful (Johns and Duquette, 1991). The practice of geophagy has been long thought to help supplement mineral nutrients and have detoxifying effects (Johns and Duquette, 1991). The nutritional benefit has been speculated, because soil contains large quantities of macronutrients and micronutrients (Abrahams, 1997). Young (2010) in a study on the association of pica with anemia and gastrointestinal distress among pregnant women in Zanzibar found out that there was a strong additive relationship of geophagy and amylophagy with lower hemoglobin (Hb) concentration and iron deficiency anemia.

The sensory and physiologic theories center on the finding that many patients with geophagy say that they just enjoy the taste, texture, or smell of the item they are eating (Sayetta, 1986). Geophagy has been used to alleviate nausea by some patients and can give a sense of fullness to patients who are trying to lose weight (Sayetta, 1986).

A neuropsychiatric theory is supported by evidence that certain brain lesions in laboratory animals have been associated with abnormal eating behaviors, and it is postulated that pica might be associated with certain patterns of brain disorder in humans (Sayetta, 1986).

Psychosocial theories surrounding pica have described an association with family stress. (Sayetta, 1986 and Edwards et al., 1994).
1.3 Problem Statement

Geophagy significantly increases the risk of infestation with *Ascaris* (Wong et al., 1988). Eating soil can also physically damage the intestinal mucosa and reduce ability to absorb nutrients (Kosuke et al., 2009). Soil can also effectively bind and make unavailable nutrients that were already present in diets particularly iron and zinc (Hooda et al., 2004). Soil often contains high levels of aluminium and available information indicates that aluminium could reduce serum ferritin and deplete iron stores (Lin and Leu, 1996). Anaemia, whether or not the primary cause is iron deficiency, is generally recognized as the main nutritional problem in adolescents (WHO, 2005). Adverse effects of anemia range from severe morbidity to decreased physical work capacity to deficits in cognitive development and potentially school performance (Leenstra, 2003). Iron deficiency may alter cognitive function in children (Pollitt et al., 1985) and even in adolescents (Ballin et al., 1992) and the effects may be only partly reversible in severe and prolonged cases.

Information on the relationship between geophagy with iron status and anaemia is still sparse. It has not been clearly elucidated whether it is geophagy that causes iron deficiency, or it is iron deficiency that causes geophagy, so that even when adequate iron is ingested, there could still be an apparent deficiency.

1.3 Justification

This study endeavored to identify the association of geophagy with iron deficiency and attempted to assess the possibility of a food replacer to geophagy to avoid soil eating which may lead to worm infestation. The study additionally tried to establish the socio-demographic and nutritional factors associated with geophagy.
The results of the study provide data to health providers to help reduce the practice and reduce incidences of parasitic worm infestation. This study was designed to utilize traditional foods to develop a soil replacer. Millet grains, amaranth grains and termites were used to develop the replacer because they are presumed to contain high levels of iron. Moreover, they are common and familiar foods in the area of study, yet not widely utilized. The non-availability of ready to use processed millet based foods has limited the usage and acceptability, despite their nutritional superiority. There is a need to provide millet based food products in the form of ready to use grains, convenience foods or mixes to meet the demands of the present day consumers. In addition, value addition of millets not only offers variety, convenience and quality food to consumers, but also helps in revival of millet cultivation. The study will therefore help the community to appreciate the potential of traditional foods in improving nutrition and substituting unhealthy pseudo-food consumption.

Adolescence, a period of transition between childhood and adulthood, is crucial position in the lives of human beings (Anand et al., 2004). Adolescence is second to infancy, as the period of most rapid growth. During this period with inadequate and improper dietary habits, one is vulnerable to all kinds of nutritional morbidities. Adolescence is therefore, considered most appropriate period to intervene, and behavior change messages embraced by this group can contribute to sustained health impacts. Early intervention is particularly critical in adolescent girls whose nutritional status is marginal to begin with, so that they enter their first pregnancy in a better nutritional state.
1.4 Main Objective

Development of a food product as replacer for geophagy in adolescent girls and evaluation of its efficacy on geophagic behaviour of adolescent high school girls.

1.5 Specific Objectives

1. To establish the baseline characteristics of adolescent girls with geophagy.

2. To identify the predictors of geophagy among adolescent girls

3. To formulate a product rich in iron from millet, amaranth and termites and feeding of the product to the girls as a replacer for geophagy.

4. To determine the iron content of the foods and formulations

5. To determine the Haemoglobin status of geophagy in adolescent girls.

6. To determine the impact of the food product on the iron status of adolescent girls.
CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of the existing and available secondary data and information on the practice of consumption of pica: The possible causes and implications of the practice, and the consequences, with a view to showing the gaps in knowledge. The chemical characteristics of the two grains (millet and amaranth) used in the formulation of the intervention food are also reviewed.

2.2 Nature and Prevalence of Geophagy

Soil or clay eating has been reported among women, from almost every part of the world. The custom exists in Nepal, Africa, India, and Central America. In various parts of the world, and at different periods in history, entire populations have been known to consume soil (Hunter, 2004). The practice is described in the Northern and Southern Americas as well as on the continent of Europe and the British Isles. Between 8%-65% of African-American women practice pica, including eating of, not only clay and soil, but also ice, baby powder and laundry starch (Boyle and Morris, 1999). Blocks of magnesium carbonate are available at pharmacies in both Mexico and California and women purchase those for consumption instead of eating clay (Simpson, 2002). In Germany, healing soil is commercially available and used as medicine against diarrhoea and gastric hyper-acidity (Höllriegel et al., 2007). In Britain, it is possible to purchase soils imported from South Asia (Abrahams et al., 2006).

Geophagy is common among women and children in African countries. It has been reported in Cameroon, Nigeria, Ghana, Sierra-Leone, South Africa, Malawi, Zanzibar and Zambia (Tayie, 2004). In Zambia brown and white earths are sold on the streets (Nchito et al., 2004).

Consumers are very selective in gathering clayey soil for geophagy taking in consideration the colour, odour, flavour and texture (Reilly and Henry, 2000). The clayey soil is obtained
from specific areas such as pits, river banks and termite mounds and consumers have
different preferences in the preparation of clays that they consume. Once the soil is obtained
from a selected spot it is shaped and dried in the sun or in an oven (Reilly and Henry, 2000).
The colour of the clayey soil is apparently important for the consumer in that it gives an
indication of the contents of the specific soil or clay. White clay largely consists of kaolin
(Yount, 2005) which has the ability to absorb toxins and bacteria and is therefore
commercially manufactured and sold as a remedy against diarrhea (Knishinsky, 1998). A
survey undertaken on school children found that brown earth was the most popular and white
clay the second most popular soil consumed by Zambian children (Nchito et al., 2004). Red
clay is rich in oxides of iron and aluminium (Yount, 2005). When iron is in the ferrous-oxide
state it is poorly absorbed by the human body (Yount, 2005).
Although the geophagic materials typically are described as “soils”, a more accurate
description for some would be “saprolites” in that they resemble decomposed and easily
disaggregated rock, such as that often found at the base of soil profiles developed by in situ
weathering (Young et al., 2010). A study in Zambia showed that 70.5% of the subjects
preferred clay to other types of soils, 19.6% cited dry termite mound from tree trunks in
combination with other types, 8.04% mentioned hut brick, and two 1.8% cited stone as the
types of soil they preferred to eat (Shinondo et al., 2009).
In Kenya, previous studies on Geophagy among school going children and pregnant women
in Western Kenya have been described by Gessler et al. (1997). They found out that over
70% of a sample of school going children in Nyanza province was found to consume soil at
an average rate of approximately 30 mg daily. The eaten soils were mainly from termite
nests, weathered stones and walls of huts. It has been reported among pregnant and lactating
women in Bondo (Luoba et al., 2004) and Kilifi (Geisler et al., 1999).
2.3. **Geophagy and Helminth Infestation**

A study conducted by Gilardi et al. (1999) on the Peruvian rainforest, showed that geophagy has three possible functions among them that of providing essential minerals. Soils sold in Ghanaian markets were found to be richer in iron and copper than the nutrient supplement pills for prenatal use from pharmaceutical companies (Diamond, 1998). In humans, geophagy has been said to be useful as: famine food, food detoxifier to counteract toxins and poisons (Diamond, 1998); supplement for nutritional deficiency, (Vermeer and Frate, 1979) and prophylaxis, for example, Kaopectate, used to treat diarrhoea and acid-stomach upset (Diamond, 1998).

Geophagy has also public health implications as it can expose the consumers to elements that are hazardous to human health like cadmium and arsenic and to helminthes infestation (Calabrese et al., 1997). Well-preserved helminthes ova were recovered in soil samples from archaeological excavations (Bouchet, 1997). These reports however, did not indicate whether or not viability tests were performed on ova from these archaeological soil samples. Twelve coprolites and 66 soil samples from 41 pits, dating from 11th to 16th centuries A.D. were examined and a wide spectrum of parasite eggs were recovered; especially from soil samples. Identified ova included *Trichuris, Ascaris, Metastrongylus, Heterakis, Ascarida, Fasciola hepatica* and *Toxocara* (Bouchet, 1997). Parasite ova recovered from other archeological samples included the four genera; *Trichuris, Ascaris, Taenia* and *Dicrocoelium* (Taylor, 1955).

A study on school children in Western Kenya showed that geophagy does not directly contribute substantially to the infestation with soil-transmitted helminthes (Geisler et al., 1997).
A cohort study on the role of geophagy and other risk factors for helminthiasis in pregnant and lactating women showed that geophagy significantly increased the risk of infection with *Ascaris* after anti-helminthes treatment (Wong et al., 1988).

### 2.4 Geophagy and Iron Deficiency

Iron deficiency and iron deficiency anaemia (IDA) in adolescence is a major public health problem. Studies indicate that the incidence of anaemia in adolescents tends to increase with age and corresponds with the highest acceleration of growth during adolescence. The highest prevalence is between the ages of 12-15 years when requirements are at peak. More than 50% girls in this age group have been reported to be anemic. Estimated prevalence of anemia in adolescents was 27% in developing countries, and 6% in industrialized countries (WHO, 2005)

A cross sectional study done in western Kenya revealed that the prevalence of anemia (Hb<120 g/l) was 21.1%. (Leenstra et al., 2004).

Geisler et al. (1998) in a study among children in western Kenya found out that the mean haemoglobin (Hb) concentration was 12.7 g/dl Analysis of the soil eaten by the children revealed a mean HCl-extractable iron content of 168.9 mg/kg (SD 44.9). Based on the data on the amounts eaten daily and this mean iron content, it is concluded that soil could provide on average 4.7 mg iron to a geophageous child (interquartile range 2.1-7.1 mg), which is equivalent to 32% of the Recommended Nutrient Intake (RNI) for girls.

Geophagy has been associated with iron deficiency and anaemia, but no causal relationship has been established. To clarify this, Nchito et al. (2004) conducted a two-by-two factorial randomized, controlled trial on the effect of iron and multi-micronutrient supplementation on
geophagy in Zambian school children in Lusaka. Geophagy was reported by 74.4% and more often in girls than in boys.

The mean (range) daily earth intake was 25.2 (1-200) g. Geophageous children had more often geophageous relatives than non-geophageous. Among those with Hb< 130 g/l, geophageous children had significantly higher prevalence (53.7%) of *Ascaris lumbricoides* infection than non-geophageous.

In this study bivariate analysis showed that non-iron supplementation reduced the prevalence of geophagy more than iron supplementation did, but this was not confirmed in the multiple logistic regression analysis. Multi-micronutrients had no effect on either geophagy prevalence or earth intake. Geophagy was prevalent and associated with iron deficiency, but iron supplementation had no effects on geophageous behaviour. They concluded that geophagy could be a copied behavior.

Clayey soils consumed by humans are rich in macro- and micronutrients but these elements are not necessarily absorbed by the gastro-intestinal (GI) system (Hooda, 2004). The soil may actually reduce/absorb the already available elements in the GI system, thereby further diminishing nutrient levels and preventing the absorption of minerals from food (Dominy et al., 2004).

Iron deficiency is usually considered to develop in three sequential stages: depletion of iron stores, iron deficient erythropoiesis and overt anemia with low hemoglobin (Hb) levels. These direct indicators for assessment of iron deficiency use blood parameters that are reflective of one or more of the above stages (Bothwell et al., 1979).

Of the many micronutrients that are considered lacking in the diets of adolescent girls, iron is the most extensively investigated. This is because anemia, attributable to iron deficiency is a major problem in developing countries (WHO, 1992). The earliest sign of iron deficiency is a
depletion of iron stores that can be assessed by staining the bone marrow for iron (Bothwell et al., 1979). A high correlation has been shown between stainable iron in bone marrow and serum ferritin levels (Lipchitz et al., 1974).

Since serum ferritin estimation is carried out more readily and serves as an indicator of iron reserves in the body, it has been used extensively in assessing the magnitude of iron deficiency, often in conjunction with Hb levels. Hemoglobin, the most extensively used parameter, is a reflection of end stage iron deficiency. A single Hb estimation may be insensitive and non-specific. Hemoglobin response to iron treatment is more sensitive and specific and it is a relatively simple parameter to use in the field setting. A combination of low Hb and low serum ferritin is recommended to detect anemia due to iron deficiency because other causes of anemia such as infections are not characterized by low serum ferritin levels. Given the interaction between several dietary constituents and iron which result in poor absorption of iron (Yip and Dallman, 1996), total dietary iron intake by itself is not a valid indicator of iron deficiency in the population unless it is accompanied by a reliable estimate of the bioavailability of iron.

Bio-available iron intake, especially its distribution in comparison with distribution of requirements for different age and sex groups can provide useful information concerning the extent of deficiency. The indirect indicators that could give a rough estimate of iron deficiency problems in the population are the extent of parasitic infestations and infections, which are indicative of poor utilization of iron.

2.5 Food based Intervention in Micronutrient Deficiencies.

A wide application of proper technologies and approaches, and development of new concepts that should be transmitted to households and stakeholders are necessary for promotion of dietary interventions in micronutrient deficiency states.
Transfer of indigenous knowledge and skill in food processing, presentation and meal combination from the older population to the younger, and building on their knowledge for production, processing and preservation of food is necessary for control of micronutrient deficiencies (Khakoni, 2009).

There have been notable changes in food selection patterns and traditional methods for preparing and processing of indigenous foods with implications of nutrient retention and bio-availability. The traditional methods are cheaper, acceptable, economically feasible and sustainable means for improved micronutrient status (Khakoni, 2009).

Of the micronutrient intervention available, effective food based strategies will be the most sustainable, as long as nutritionally adequate diets based on local foods can be successfully identified and promoted (Trowbridge et al., 1993). For this to occur, food based dietary guidelines must be formulated that are simple, realistic, regionally specific, culturally appropriate, and take into account the multiple factors influencing food choice (FAO/WHO, 1998). One of the barriers to formulating such food-based guidelines is the cumbersome, time consuming and potentially biased consultation process required to develop them (FAO/WHO, 1998).

This process would be done more effectively using a computer based modeling approach to reduce the errors and biases that can occur when using a consultation process alone. Several approaches exist for designing population specific recommendations that are based on locally available foods (Baghurst, 2003). These approaches involve expert consultation that takes into account the most common nutritional problems as well as such factors as cultural food consumption patterns, acceptable foods (available, affordable and regularly consumed), realistic food portion sizes, and the impact of recommendations on other nutrients and the environment. To facilitate this consultation processes, a multi factorial approach based on linear programming analysis, which simultaneously take into account multiple factors,
including diet, nutrient content, cost, and cultural was developed (Ferguson et al., 2004). Linear programming analysis models can be developed to formulate robust food based dietary strategies which resemble current dietary practices as closely as possible, while at the same time ensuring that diets based on them meet selected nutrient recommendations.

2.6 Nutrient Content of Millet grains, Amaranth grains and Termites

2.6.1 Millet

Millet grains (*Leusinecoracana*), Amaranth grain (*Amaranthuscruentus L*) and WingedTermite (*Macrotermessubhylanus*) are traditional foods among communities in Western province of Kenya (Orech et al., 2007). Traditional foods may contribute to a nutritionally balanced diet by supplying essential vitamins and minerals (FAO, 1988). Moreover, traditional foods adapted to local conditions contribute to the diet in periods of seasonal scarcity (Ogoye and Aagaard, 2003; Orech et al., 2007), thus contributing to an important traditional buffer against periodic famines that are becoming increasingly prevalent in other areas of the tropics.

Finger millet (*Eleusinacoracana*), typically a tropical crop, belongs to the group of minor cereals. It is mainly consumed in India and Africa (Udayasekhara et al., 1988).

It is an important cereal because of its excellent storage properties of the grains and the nutritive value, which is higher than that of rice and equal to that of wheat. It is also a good source of micronutrients like Calcium, Iron, Phosphorus, Zinc and Potassium. Poor iron availability (represented by low ionizable iron) in brown varieties is due to their high tannin content which adversely affect the nutritional quality of the grains (Udayasekhara et al., 1988).
2.6.2 Amaranth

Amaranth grain has been promoted as a cereal grain in western Kenya region for the past five years by the Kenya Government (Kinyuru and Muchui, 2009) and has been widely accepted as a nutritious food especially for infants and immune depressed persons. Amaranth grain has the potential to contribute to the nutritional needs of vulnerable individuals because of its high protein content, superior protein quality, high content of essential fatty acids and micronutrients (Tagwira et al., 2006). Amaranth has been associated with aiding recovery of severely acutely malnourished children and an increase in the body mass index of people formerly wasted by HIV/AIDS (Tagwira et al., 2006). Secondary data from Kenyan food composition tables indicate that among the cereal grains, amaranth (Amaranthus sp.) had the highest iron content (21mg/100g) (Sehmi, 1993)

2.6.3 Termites

Termites, Isoptera termitidae (known as Ng’wenin Luo, Kumbekumbein Swahili and Tsiswa in Luhya dialects in Kenya) appear to be of greater significance in diets than most ants (Kinyuru et al, 2009); however, their seasonality inhibits regular collection throughout the year. The most popular are the sexual winged forms of the larger species within lowlands. These emerge from holes at the mounds after the first rains and during the short rains, late during the last quarter of the year. The abundance of the insects may vary widely from year to year due to over-exploitation of the environment (Ferreira, 1995). Studies have showed that termites have high iron content (Sehmi, 1993) and zinc content (Lukmwaji et al., 2008).

2.7 Anti-nutritive Factors in Grains

Due to the presence in grains of such substances as tannins and phytates, micronutrients are less bio-available. These anti-nutritional factors modify the nutritional value of the individual grains. Among millets, finger millet is reported to contain high amounts of tannins
Ramachandra et al., 1977), ranging from 0.04 to 3.47. Phytates are found in all kinds of grains, seeds, nuts, vegetables, roots (e.g., potatoes), and fruits. Chemically, phytates are inositol hexaphosphate salts and are a storage form of phosphates and minerals. Other phosphates have not been shown to inhibit non-heme iron absorption. In North American and European diets, about 90 percent of phytates originate from cereals. Phytates strongly inhibit iron absorption in a dose-dependent fashion and even small amounts of phytates have a marked effect (Gillooly, 1983).

Polyphenols have been considered as anti-nutrient because they interact with food constituents and make them unavailable. Numerous experiments in both humans and animals have shown that polyphenols strongly inhibit iron absorption. This action is attributed to the galloyl and catechol groups of phenolic compounds (Bruner et al., 1989).

2.8 Shelf life of Millets and Millet based Flours

Shelf life is an important criterion determining consumer acceptability and utilization in day to day life. The commodities possessing good shelf life have good utilization potentials. The storage conditions, form of storage, packaging materials, inherent grain components and extent of heat application influence the storage quality of foods. Hence, it is important to ascertain grain storage quality for enhanced utilization.

An investigation by Chaudhary and Kapoor (1984) revealed that the whole grain and flour of pearl millet stored in gunny sacks, earthen pots, tin cans and polythene bags turned rancid on 6, 7, 8 and 10 days, respectively. Further, the meal turned inedible on days 11, 12, 13 and 14, respectively on storage. This indicated poor storage quality of whole pearl millet flour. Among the packaging materials, polythene bags were relatively good barriers and gunny sacks were the poor barriers for development of rancidity. These differences were attributed to higher moisture content and free access to air in the gunnysacks.
Kaced et al. (1984) demonstrated that ground pearl millet turned rancid due to increased fat acidity and peroxide value. The deterioration was more rapid in ground millet than in whole intact millet. The millet meal stored in polythene bags showed rapid increase in peroxide value and appeared to signal the start of rancidity. However, millet meal stored in cotton bags showed no peroxide accumulation.

Meera et al. (2003) proved that development of free fatty acids could be arrested by heat processing. Two varieties of pearl millet grains were subjected to heat treatment (98°C) for 5, 15 and 25 minutes. The processed grains were either ground as such or decorticated prior to grinding. The results indicated that heat processing for 15 min was effective in arresting the development of free fatty acid content (<10%) up to four months of storage in whole and decorticated flour of both the varieties.

It has been shown that storage stability of other cereals and oilseeds can be improved by heat-processing methods that inactivate lipid enzymes (Bookwalter, 1983). Cereals and oilseeds can be partially or fully cooked in extruder or roll cookers to inactivate hydrolytic and oxidative enzymes to improve storage stability.

Thus, suitable packaging material, storage conditions and pre-processing techniques are necessary to enhance the shelf life of millet flour.

Malted and roasted millet incorporated with ready to eat mixes for young children were formulated by Gopaldas et al. (1992). The mixes included different cereals, pulse and oilseeds (wheat, green gram and groundnut) combinations. The roasted mixes packed and stored in sealed polythene bags were in good condition at room temperature for 28 days as compared to 14 days for malted mixes.
CHAPTER THREE: STUDY DESIGN AND METHODOLOGY

3.1 Study Design

The study design was cross-sectional with analytical and interventional components. The cross-sectional component consisted of a baseline survey on prevalence and predictors of geophagy. The analytical component consisted of formulation and development of a geophagy substitute. Moreover, the interventional component consisted of a randomized control trial to assess the efficacy of the geophagy substitute.

3.2 Methodology

The study consisted of three components: baseline survey, product development and intervention

3.2.1 Baseline Survey

A cross sectional study design was used at baseline. The purpose of the study was to determine the prevalence of geophagy. It determined the baseline characteristics of the respondents in a bid to determine the significant predictors of geophagy. Cross sectional studies are suitable for determining prevalence or incidences at a point in time.

3.2.1.2 Study Setting for Baseline Study

The baseline survey was done in two girls boarding schools in Likuyani Sub County of Kakamega County. Kakamega county has seven Sub Counties. These are; Butere, Ikolomani, Khwisero, Lugari, Navakholo, Likuyani and Lurambi. Likuyani sub-county was randomly sampled from the six districts. Likuyani sub-county has two boarding schools. The two schools are; Moi girls Nangili and St Annes’ Nzoia.
3.2.1.3 Study Population for Baseline Survey

All girls in the two secondary schools formed the population of the study. The total population of students in the two schools was 1470. Moi girls Nangili had a student population of 750 while St Annes’ had a population of 620 students.

3.2.1.4 Sample Size Determination for Baseline Survey

The prevalence of geophagy among girls in Kenya was reported to be 74.4 % (Grislier et al., 1998). This prevalence was used to calculate the sample size. A formula of calculating sample size in epidemiological studies when random sampling is to be used in sampling was used to calculate the sample size (Thrusfield, 2005).

\[
    n = \frac{1.96^2 \times P_{exp} (1-P_{exp})}{d^2}
\]

Where:
- \( n \) = required sample size
- \( P_{exp} \) = expected prevalence
- \( d \) = desired absolute precision = 0.05

\[
    n = 1.96^2 \times 0.73(1-0.73)
    \]

\[
    n = \frac{0.05^2}{0.05^2}
    \]

\[
    n = 302
\]

3.2.1.5 Sampling Procedure for Baseline Survey

A sample of 302 girls was proportionately drawn from the two schools. Fifty one percent (154 girls) of the sample was drawn from Moi girls Nangili while 49% (148 girls) came from St Annes’. Stratified random sampling was used to come up with a representative sample that included girls from all classes. The samples were also proportionately drawn from the classes.
Before the process of recruitment commenced, the school Principals and administrators were asked to include a short study advertisement in school newsletters, school notice boards and school counselors were provided with flyers to distribute.

The researcher after consultation with the administrators of the two schools gave presentations to all the girls in the two schools. The sessions were done for each class. The researcher introduced the research issue to the students. The background, purpose of the study, voluntary participation, eligibility and randomization during the recruitment were highlighted during the sessions. The girls were allowed to ask questions and raise any concerns about the research. After the session those willing to participate remained in the room as others left. The remaining girls were given numbers which were recorded against their names. This was repeated for all the four classes. Then using the random number tables a proportionate sample was drawn from each class based on the population of the class. A statistician carried out the randomization process.

3.2.1.6 Inclusion and Exclusion Criteria for Baseline Survey

All girls in schools had a chance of participating in the study. Those who were pregnant were not eligible for participation.

3.2.1.7 Data Collection for Baseline Survey

Socio-demographic data, nutritional characteristics, geophagy and nutrient status were collected. A structured questionnaire was used to collect baseline data. Anthropometric measurements of height, weight and mid upper arm circumference of the participants were taken. Height and weight measurements were used to compute the body mass index (BMI) of the participants.
Weight was taken to the nearest 0.1kg using an electronic scale (SECA) as follows: The scale pointer was adjusted to zero. The participants were in light clothes, removed shoes and scarves as the measurements were taken. Participants stood straight at the center of the platform.

Height was measured to the nearest 0.1cm using a height meter as follows: Participants were asked to remove shoes, stand erect, looking straight in a horizontal plane with feet together and knees straight.

Each measurement was taken twice on each respondent and the average taken to ensure accuracy. Body mass index was computed as weight/height (m$^2$) (Gibson, 1990).

Mid upper arm circumference (MUAC) of the participants was also be taken as follows: A flexible non-stretch tape was used to take the measurement, the participant was asked to stand erect and sideways to the measurer with the head in Frankfurt plane, arms relaxed and legs apart (Gibson, 1990). The measurement was taken at the midpoint of the left upper arm between the acronium process and tip of the olecranon. The measurement was taken to the nearest millimeter (Gibson, 1990).

Data on dietary intake of iron was collected using the 7 days record method from the school meals. The type of food eaten, and the volume of cooked food consumed by the enrolled girls was recorded using standard tools (utensils). The data obtained was used for calculating the amount of food consumed and subsequently nutrient intake of the girls. The intake of iron was obtained by using the food composition tables and nutrient calculator.
3.2.2 Product Development

The product comprised of millet, amaranth grains and termites. Linear programming was used to formulate diets that are nutritionally adequate in iron from the grains. Nutri Survey (2007 version) was used to come up with four formulations of varied ingredient proportions as indicated in table 3.1. The products from the formulations were then tested using taste panel procedures. The acceptable formulation with the highest micronutrient content was adopted.

3.2.2.1 Study Setting for Product Development

The product was developed at Kabete campus Food science laboratory. All analyses including analysis of ingredient, product and keeping quality of product were done at the same laboratory. Taste panel tests were done at St Annes’ Nzoia School where the intervention study was to be done.

3.2.2.2 Product formulation

A mix of finger millet grains, amaranth grain and termites was used to come up with four formulations as indicated in Tables 3.1.

<table>
<thead>
<tr>
<th></th>
<th>Formulation 1</th>
<th>Formulation 2</th>
<th>Formulation 3</th>
<th>Formulation 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finger millet (g)</td>
<td>100</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Amaranth (g)</td>
<td>0</td>
<td>15</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Termites (g)</td>
<td>0</td>
<td>15</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Iron content (mg)</td>
<td>9 mg</td>
<td>20.6</td>
<td>20.6</td>
<td>20.4</td>
</tr>
</tbody>
</table>
3.2.2.3 Preparation of the Raw materials and Snack

The grains were selected to remove any foreign materials like stones and debris, sand or other seeds that are not part of the ingredients. Dried termites were bought from the market. Sun drying was done thoroughly to avoid development of aflatoxin in cereals. Grinding was done using a flour miller.

The flour was hydrated at a ratio of 500g of flour to 300ml of water; these was then mixed using a wooden spoon to a thick consistency. Approximately 8 mm thick layer of the mash was spread on baking trays then baked in an oven at $120^\circ C$ for one and a half hours. The product was then dried in an oven at $40^\circ C$ for one hour. The product was allowed to cool, then packaged in polythene bags and sealed. It was stored in a cool and dry place. This procedure is shown in Figure 3.1
Dried Finger millet grains  |  Dried Amaranth grains  |  Dried termites

Sorting  

Blending

Milling

Flour

Hydration (300mls water: 500g flour)

dough

Baking (120°C -12hrs)

Snack

Drying (40°C -1hr)

Dried snack

Packaging

Storage

Figure 3.1: Product Development process
3.2.2.4 Sensory Evaluation of the Product

Taste panel procedures generally require the tasting of two or more samples and decisions are made on the basis of comparison as to difference and preference.

The Four samples of the meal prepared above were presented to panel members at one time and compared and packed to identify the most preferred mix. The code letter identifying each sample were placed on the bottom of opaque cups, only the number 1, 2, 3 or 4 were visible on the sides of the cup. Tasters used their mouths between tastings and were advised to base their judgment on a specific quality factor or attribute of the product colour, flavor, taste and odour. The tasters were properly instructed on how to test for the attributes in question. A spoon full taste was taken from each of the four cup. This was done so as to obtain similar orientation for each test since taste response could be influenced by previous taste experiences. Tasters were advised to wait for about one minute before assigning an attribute to the sample and another one minute before tasting the next sample. This was to avoid mixing up of the sample tastes. A taste panel form (appendix VI) was given to the taster to complete after tasting.

Ten girls were selected for the taste panel; then the taste panels’ results were subjected to analysis of variance to determine the preference of the samples and the most preferred was used for the intervention study.

3.2.2.5 Evaluation of the Keeping Quality of the Product

The most preferred product, which was used for the study, was evaluated for property. The product was packed and heat-sealed in polyethylene bags and kraft paper bags. One set was stored at a temperature of 25°C and another at 35°C in aluminium boxes peroxide value were analyzed at the beginning of the storage, after two weeks and at monthly intervals up to a period of three month. Peroxide value was analyzed using the AOCS (1993)
3.2.3 Analytical Methods

3.2.3.1 Determination of Protein
Protein was determined as total nitrogen by the Kjeldahl method AOAC (2007), using Pelican Kelplus equipment. Crude protein was calculated by multiplying percent nitrogen by factor 6.25.

3.2.3.2 Determination of Crude fat
About 100g samples were weighed accurately in moisture free thimbles and crude fat was extracted by refluxing with petroleum ether in a soxhlet apparatus by AOAC methods (AOAC, 2007). Percent crude fat was calculated.

3.2.3.3 Determination of Crude fibre
Crude fibre was estimated from the moisture and fat free sample by AOAC methods (AOAC, 2007). The residue obtained after digestion with acid and alkali was dried in crucible and weighed. The difference in weight of the crucible before and after ashing of the digested residues was taken as weight of the crude fibre.

3.2.3.4 Determination of Total Ash
Total ash content was determined by AOAC methods (AOAC, 2007) by igniting the about 100g samples accurately weighed in porcelain crucibles in a muffle furnace at 600°C for 3-4 hours. The ash residue was cooled in a dessicator and weighed.

3.2.3.5 Determination of Soluble Carbohydrates
The total soluble carbohydrate content was calculated by difference method after subtracting the sum of the values for moisture, protein, fat, ash and crude fiber from 100.
3.2.3.6 Determination of Iron content of Food samples
Iron was analyzed following the standard procedure of AOAC (2007). A flour sample of 5 g was weighed accurately. The sample was charred and ignited in a muffle furnace at 600°C for 6 hours. The ash was digested in 15 ml of concentrated hydrochloric acid and volume made to 100 ml in a volumetric flask and filtered through Whatman No.1 filter paper. The filtrate was used for the estimation of iron.

3.2.3.7 Determination of Phytochemicals in the Food samples
The tannin content of the grain sample was assessed using the (AOAC, 1975). The concentration of tannin was calculated by referring to the standard curve of tannic acid and expressed as mg/g of the sample. Phytates were estimated as phytic acid and the phytate phosphorus was obtained (AOAC, 1980).

3.2.3.8 Determination of Heamoglobin level in Blood
Blood samples of about 5ml were taken at baseline and after intervention and stored in ice for transportation to the laboratory.
To examine the extent of iron deficiency, a trained laboratory technician carried out a complete hemogram analysis of the blood samples to determine iron deficiency. A coulter counter was used, hemoglobin (Hb), haemacrit (Hct) and MVC were recorded. Nutritional anemia was assessed by using both hemoglobin and haemocrit. Girls were categorized as having iron deficiency anemia when found with Hb of < 12g/dl.

3.2.3.9 Determination of Helminthes in Stool Samples
The participants were given sterile labeled containers and plastic spoons to collect feacal samples and deliver them immediately after collection for proper storage. They were instructed to collect atleast one spoon (5g) of the sample. Fecal flotation was used because
common helminth eggs and protozoan cysts are less dense than the fecal analysis solution and will float to the top of the solution where they can be collected for microscopic examination. This was done by mixing the feces with the test solution and allowing it to sit on the laboratory bench. This was followed by microscopic examination.

3.2.3.10 Determination of Iron Content in the Soil

Participants were asked to identify the termite mount in school where they collected the soil they ate, a soil sample was collected from the mount for analysis. Soil was also bought from Kitale and Nairobi markets since the participants had indicated that sometimes they bought the soil they ate.

Determination of iron in geophagic samples was done by Energy dispersive X-ray fluorescence spectroscopy (XRF) using PAN-analytical Minipal QC model and Atomic absorption spectrometry (using 210 VGP AAS model). XRF analysis was performed on pressed-powder disks. For analysis of iron 2.5 g of pulverized sample was placed in a 200ml beakers, 10 ml of distilled water was added to make a slurry, 15mls of concentrated HCl and 5mls of concentrated nitric acid was added. The samples were digested for at least 10mls in a hot plate. The solutions were filtered into 50mls volumetric flask and the filter paper washed thoroughly with hot water. The solution was topped with distilled water and shaken well. This solution was then analyzed with AAS.

Standard procedures for the preparation of stock solutions for iron was employed. The standard stock solutions was used to prepare serial solutions for the determination of iron in the sample using AAS.

3.2.3.11 Analysis of Helminthes ova in Geophagic Soil Samples

For analysis of helminthes in the soil, soils in 3mg samples were dissolved in water and the mixture sieved through gauze lined tea strainer. This was repeated several times to remove
large particles of debris. Then Zinc sulphate and saturated sodium chloride floatation, as well as the sedimentation techniques for ova isolation were applied.

3.2.3.12 Cost Analysis of the Product

The average cost per Kilogram of millet, amaranth and termites is Ksh 87,100, and 250 respectively. The cost of producing one kilogram of the product is shown in Table 3.2. In case the users consume 30g in a day then they could spend Ksh 6.10 in a day. On average a consumer may consume approximately 200g of the product per week, this would cost her approximately Ksh 40.50. The cost of 200g of soil in a supermarket is Ksh 20, this is half the cost of the product, however, the product has a nutritional advantage over the soil.

**Table 3.2 Cost Analysis for production of 1kg of the Product**

<table>
<thead>
<tr>
<th>Costs</th>
<th>Prices(Ksh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70% Millet (700g)</td>
<td>61</td>
</tr>
<tr>
<td>20% Amaranth(200g)</td>
<td>20</td>
</tr>
<tr>
<td>10% Termites (100g)</td>
<td>25</td>
</tr>
<tr>
<td>Milling of the mixture</td>
<td>20</td>
</tr>
<tr>
<td>Baking of the mixture</td>
<td>40</td>
</tr>
<tr>
<td>Packing (30g packs)</td>
<td>10</td>
</tr>
<tr>
<td>Total cost</td>
<td>176</td>
</tr>
<tr>
<td>Margin of 10% for sell</td>
<td>17.6</td>
</tr>
<tr>
<td>Other costs(energy water etc) 5% of total cost</td>
<td>8.80</td>
</tr>
<tr>
<td>Selling price</td>
<td>202.4</td>
</tr>
</tbody>
</table>
3.2.4 Intervention Study

A parallel group randomized control trial was used in the intervention. The randomized control trial (RCT) is the gold standard in public health and medicine when allocation of individual participants is possible (Muray, 1998). The primary goal of conducting an RCT is to test whether the intervention works by comparing it to a control condition.

3.2.4.1 Study Setting for Intervention Study

The intervention study was done at St Annes’ Nzoia girls’ school in Likuyani Sub County of Kakamega County. The school was randomly selected from the two schools where baseline survey was done. The school was boarding school, therefore admitted students from diverse ethnic and social backgrounds.

Moreover, the school is located in a cosmopolitan settlement scheme, these gave a broadly representative sample enabling the findings to be generalized to a diverse population. The administration of the intervention did not require any specialized setting or personnel therefore could be done in various setting with even less qualified personnel to administer the intervention. The analysis of blood and stool samples done at baseline and after intervention was done at the Lumakanda district hospital laboratory.

In a randomized controlled trial, participants are assigned to treatment conditions at random. Procedures are controlled to ensure that all participants in all study groups are treated the same except for the factor that is unique to their group. The unique factor is the type of intervention they receive. Random assignment ensures that known and unknown person and environment characteristics that could affect the outcome of interest are evenly distributed across conditions (Muray, 1998).

Random assignment also equalizes the influence of non specific processes that are not integral to the intervention whose impact is being tested. Nonspecific processes might include
effects of participating in a study, being assessed, receiving attention, self-monitoring and positive expectations.

Random assignment and the use of a control condition further ensure that any extraneous variation not due to the intervention is either controlled experimentally or randomized. That allows the study's results to be causally attributed to differences between the intervention and control conditions (Muray, 1998).

3.2.4.2 Sample Size Determination for Intervention Study

A randomized control trial done on adolescent girls revealed that after supplementation with iron the mean Hb for the treatment group was 13.5g/dl and that of the control group was 12.7g/dl with a common standard deviation of 0.8 (Bruner et al., 1996). A simple formula, for a two-sided test of 5%, is

\[
m (\text{size per group}) = \frac{2c}{\delta^2} + 1
\]

\[
= \frac{2 \times 10.5}{1^2} + 1
\]

\[
= 22 \text{ per group}
\]

\[
= 44 \text{ participants + 30\% (attrition)}
\]

\[
= 57 \text{ participants = 29 per group}
\]

Where \( \delta = \frac{\mu_2 - \mu_1}{\sigma} \) is the standardized effect size and \( \mu_1 \) and \( \mu_2 \) are the means of the two treatment groups. \( \sigma \) is the common standard deviation.

\( c = 10.5 \) for 90\% power at two-sided 5\%.

A sample of 58 participants was used with 29 participants in each group.

The formula was used because it's the formula of choice when there are two independent samples and when the primary outcome of interest is the mean difference in an outcome variable between two treatment groups (Chan, 2003).
3.2. 4. 3 Sampling Procedure for Intervention Study

After the baseline survey, the researcher met all the girls who participated in the survey in the school where the intervention was to be done. During the meeting the researcher requested to have a session with the girls who had indicated that they were geophagic during the survey. Those who are not geophagic were allowed to leave. During the session with the geophagic girls, the researcher introduced the aspect of the intervention giving all the details of the intervention including eligibility criteria and randomization to the two groups. The girls were asked to volunteer and assured that there would be no victimization for whatever decision made. Those willing and those who did not meet the eligibility criteria were allowed to leave. The enrollment procedure was done as shown in Figure 3.2.

Those who volunteered to participate in the study were stratified according to class and randomized the treatment groups A and B. A statistician determined the allocation sequence, random number tables were used, and the randomization was implemented by the statistician. Permutated blocks were created for each class. Each block had equal number of treatments (A) and controls (B). Blocks of four (4) were created; a total number of six (6) blocks per group were created. The blocks were chosen at random using random number tables and treatments allocation done according to that block, then another block was chosen at random and treatments allocated according to that block, this was done until the required sample size was reached. Allocation concealment was achieved through use of sequentially numbered opaque sealed envelopes. The researcher determined which group will be the treatment and control. Randomization was done by a person who did not have any other responsibility in the course of the research to avoid bias.
3.2.4.4 Inclusion and Exclusion Criteria during Intervention Study

All girls in school who were found geophagic at baseline were eligible for participation in the study. Girls who were receiving iron supplements of those sensitive to the ingredients used to develop the product were not eligible for participation.
3.2.4.5 Data Collection during Intervention

The 58 girls were distributed in two groups as follows: an intervention group and a control group. Immediately before the intervention, the participants filled questionnaire, blood and stool samples were collected; this was done by a trained laboratory technician. Soil samples eaten by the participants were also collected and analyzed to determine the amount of iron and presence of helminthes.

Albendazole (400 mg) single dose and was given to both groups as treatment to helminthes infestation and malaria prophylaxis respectively at the beginning of the study. The treatment group was given the snack but the control group was not given.

The mount of snack given per day was 30g this was the average amount of soil eaten per day as determined at baseline. The researcher gave the snack to the participants daily and built confidence in them to ensure compliance. An intervention schedule (register) was used, the schedule comprise d of the name, class, and date/day of snack collection. The register helped in monitoring progress of the intervention. The participants were advised to treat the snack as a treatment and not to share out to friends to ensure compliance and avoid contamination. Participants were advised to eat the snack any time they felt like eating soil. Each time the participants went to collect the snack, the researcher discussed with each one of them about the intervention snack and its importance to ensure compliance. The participants were encouraged to report any side effect caused by eating the snack. The behavior of eating soil among the participants of the treatment group was also be monitored.

Participants in the control group were advised not to share the snack with those in the treatment group. They were advised to take some little soil whenever they felt the urge. They
met the researcher at least once in a week, during the meeting they discussed the frequency and amount of soil they ate and any side effects.

Data on geophagy and hematological status was collected eight weeks after enrolment. All girls were interviewed to obtain information about geophagy. Out of the 58 girls who were enrolled for the study, only 55 completed. Three girls dropped out of the study.

3.2.4.6 Outcomes

The expected outcomes of the intervention study are changes in geophagic behavior and improvement of hemoglobin status of the participants.

3.3 Data Analysis

Statistical package of social scientist (SPSS) version 17 was used in data analysis. Data collected at baseline and after the intervention were analyzed. The data were coded after collection; it will then be entered into SPSS program for analysis.

Descriptive statistics were used to summarize data. Frequency tables were used to summarize data on the general characteristics and nutrition data of the respondents. Chi-square tests were done to test the differences between the treatment group and control group on categorical variables. T-tests were used to determine the differences in mean micro nutrient values between the intervention group and the control group. The statistical significance was set at $p < 0.05$. A multivariate logistic regression was used to determine the significant predictors of geophagy. Mixed ANOVA was used to determine variation in sensory attributes of the products developed.
Table 3.3: Data analysis matrix

<table>
<thead>
<tr>
<th>Type of data</th>
<th>Method of analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline data</strong></td>
<td></td>
</tr>
<tr>
<td>General characteristics</td>
<td>Frequencies, chi square</td>
</tr>
<tr>
<td>Anthropometric</td>
<td>Mean, t-test</td>
</tr>
<tr>
<td>measurements</td>
<td>(height weight, BMI, MUAC)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dietary data</strong></td>
<td></td>
</tr>
<tr>
<td>Type of food</td>
<td>Frequency</td>
</tr>
<tr>
<td>Nutrient intake</td>
<td>Mean, t-test</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Predictors of geophagy</strong></td>
<td>Multivariate Logistic regression</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Product development</strong></td>
<td></td>
</tr>
<tr>
<td>Taste panel data</td>
<td>Mean, mixed ANOVA</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intervention phase</strong></td>
<td></td>
</tr>
<tr>
<td>Hematological data</td>
<td>Mean, independent sample t-test</td>
</tr>
<tr>
<td>Data on geophagy</td>
<td>Frequency, chi square</td>
</tr>
</tbody>
</table>

3.4 Ethical Considerations

The proposal was submitted to Ethical Research Committee of the University of Nairobi for approval. Consent was also sought from the school administration of the participating schools. Participants eighteen years and above read and signed the consent form attached on the questionnaire, those under eighteen had their consent forms signed by their parents but they signed assent forms. Participation in this study was voluntary and participants were free to withdraw from participation if they so wished.

Parents of participants under the age of 18 were contacted through phone calls and the research issue explained to them. Those who accepted to have their daughters participate were further invited to school through the school administration. They were then given the forms to read and allowed to ask for clarification of any issues they had before signing. The child also signed the assent form after the parent consenting. Participation was only after the consent had been approved. Questionnaires had numbers rather than the name of the
participant to ensure confidentiality; however, the intervention schedule had the name and the number for easier monitoring. Girls who were allergic to any of the ingredients used to make the snack were not allowed to participate in the study. Any information obtained from the respondents was treated in confidence and only for the purpose of the study.
CHAPTER FOUR: RESULTS

4.0 Introduction

This chapter presents the results of the study including results of baseline study defining the prevalence and risk factors of geophagy and anemia. Further, it presents the results of the development of the food product, which acted as a soil replacer in the intervention study. Additionally, a study evaluating an intervention to assess the effectiveness of the replacer.

4.1 Baseline Survey

4.1.1 Prevalence of Geophagy

Out of the 302 respondents interviewed, 135 (45%) were practicing geophagy. As presented in Figure 4.1.

![Prevalence of anemia](image)

**Figure 4.1 Prevalence of Geophagy**
4.1.2 Socio-demographic Characteristics of the Respondents

The socio-demographic characteristics of the study population are represented in Table 4.1.

Table 4.1 Socio-demographic Characteristics of the Respondents and their Families at Baseline.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Geophagous</th>
<th>Non geophagous</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=135 n(%)</td>
<td>n=167 n(%)</td>
<td></td>
</tr>
<tr>
<td><strong>School</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St Annes</td>
<td>67(50)</td>
<td>81(49)</td>
<td>0.469</td>
</tr>
<tr>
<td>Nangili</td>
<td>68(50)</td>
<td>86(51)</td>
<td></td>
</tr>
<tr>
<td><strong>Class</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form 1</td>
<td>23(17)</td>
<td>50(30)</td>
<td>0.001</td>
</tr>
<tr>
<td>Form 2</td>
<td>52(38)</td>
<td>22(13)</td>
<td></td>
</tr>
<tr>
<td>Form 3</td>
<td>33(25)</td>
<td>43(26)</td>
<td></td>
</tr>
<tr>
<td>Form 4</td>
<td>27(20)</td>
<td>52(31)</td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13-15</td>
<td>43(32)</td>
<td>50(30)</td>
<td>0.354</td>
</tr>
<tr>
<td>16-20</td>
<td>86(64)</td>
<td>114(68)</td>
<td></td>
</tr>
<tr>
<td>&gt;20</td>
<td>06 (04)</td>
<td>03(02)</td>
<td></td>
</tr>
<tr>
<td><strong>Geophagic mother/guardian</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>82(60)</td>
<td>68(41)</td>
<td>0.001</td>
</tr>
<tr>
<td>No</td>
<td>53(40)</td>
<td>99(59)</td>
<td></td>
</tr>
<tr>
<td><strong>Mothers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Education level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>06(04)</td>
<td>20(12)</td>
<td>0.001</td>
</tr>
<tr>
<td>Secondary</td>
<td>48(36)</td>
<td>83(50)</td>
<td></td>
</tr>
<tr>
<td>Certificate/diploma</td>
<td>69(51)</td>
<td>37(22)</td>
<td></td>
</tr>
<tr>
<td>Graduate</td>
<td>12(09)</td>
<td>27(16)</td>
<td></td>
</tr>
<tr>
<td><strong>Mothers profession</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>House wife</td>
<td>44(33)</td>
<td>71(43)</td>
<td></td>
</tr>
<tr>
<td>Business woman</td>
<td>14(10)</td>
<td>35(21)</td>
<td></td>
</tr>
<tr>
<td>Farmer</td>
<td>71(53)</td>
<td>54(32)</td>
<td></td>
</tr>
<tr>
<td><strong>Family size</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤5 members</td>
<td>55(41)</td>
<td>43(26)</td>
<td>0.007</td>
</tr>
<tr>
<td>&gt;5 members</td>
<td>80(59)</td>
<td>124(74)</td>
<td></td>
</tr>
<tr>
<td><strong>Home setting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>70(52)</td>
<td>106(64)</td>
<td>0.046</td>
</tr>
<tr>
<td>Urban</td>
<td>65(48)</td>
<td>61(36)</td>
<td></td>
</tr>
</tbody>
</table>
Results in Table 4.1 show that 67 (50 %) of the geophagic girls came from St Annes’ school while 68 (50 %) from Nangili school and thus there was no significant difference in the distribution of geophagy between the two schools (p= 0.469).

Most of the geophageous girls 52 (39%) were members of form two class, while 23 (17%), 33 (25%), 27(20%) were members of form one, three and four respectively. Among the non geophageous group 50(30%), 22(13%), 43 (26%) and 52 (31%) were members of form one, two and three respectively. The distribution of the respondents among the classes differed significantly (p= 0.001).

Majority of the respondents both geophageous 86(64%) and non geophageous 114(68%) were of age 16-20. More than half 82(61%) of the geophageous girls indicated that their mothers/guardians were geophageous. However, 68 (41%) of the non geophageous girls also indicated that they had geophageous mothers/guardians, there was a significant difference between the two groups (p= 0.001).

The educational profile of the mothers differed significantly (p= 0.001). Most 69(51%) of the mothers/ guardians of geophageous girls had attained either a certificate or diploma course, while most 83(50%) of the non geophageous girls had attained secondary level of education. Few 11(19%) of the mothers/guardians had primary level of education.

Most 71(53%) geophageous girls had mothers with a professional job. While most 71(43%) non-geophageous girls had mothers who were businesswomen, the profession of mothers differed significantly ( p = 0.002) between the two groups.

Distribution of the respondents by family size differed significantly (p= 0.007) between the geophageous group and non geophageous group. Majority of the non geophageous 124 (74%) respondents compared to the geophageous 80 (59%) indicated that they came from families of more than five members.
The respondent’s home setting was either rural or urban. Majority of the non geophageous girls 106 (64%) compared to the geophageous girls 70(52%) were from the rural setting. This showed a significant difference between the two groups (p = 0.046) (Table 4.1).

4.1.3 Diet of the Respondents

The average weekly meals of the schools from which the respondents were sampled is shown in Table 4.2.

Table 4.2: Weekly Food Consumption of the Respondents in the two schools

<table>
<thead>
<tr>
<th>Type of food</th>
<th>Frequency(days) in a week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>St Annes school</td>
</tr>
<tr>
<td>Maize meal porridge</td>
<td>3</td>
</tr>
<tr>
<td>Bread</td>
<td>2</td>
</tr>
<tr>
<td>Ugali</td>
<td>8</td>
</tr>
<tr>
<td>Boiled kales</td>
<td>6</td>
</tr>
<tr>
<td>Black Tea</td>
<td>2</td>
</tr>
<tr>
<td>Mixture of maize and beans</td>
<td>4</td>
</tr>
<tr>
<td>Rice</td>
<td>1</td>
</tr>
<tr>
<td>Stewed beans</td>
<td>3</td>
</tr>
<tr>
<td>Stewed beef</td>
<td>2</td>
</tr>
</tbody>
</table>

The respondents adhered to the cyclic school menu. However there was change of diet only once a month when students would be visited by their parent/ guardians. The two schools had a similar menu since they are from the same region with slight variation on the frequency of eating the foods.

The diets were limited to porridge, mixture of maize/ beans and ugali/kales with only two days of meat in a week. The diet was lacking in milk or milk product and fruits. The only vegetable served was kales.
4.1.4 Mean Nutrient Intake of the Respondents

The mean intake of protein, energy and iron are shown in Table 4.3.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Mean (SD)</th>
<th>RDA</th>
<th>% RDA</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (g)</td>
<td>43(25)</td>
<td>46</td>
<td>93.4</td>
<td>0.0001</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>1395.5(625)</td>
<td>2200</td>
<td>63.4</td>
<td>0.041</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>12.36(6.38)</td>
<td>15</td>
<td>82.4</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

As the results in Table 4.3 show, in the three nutrients, intakes satisfied more than 50% of the RDA requirements, however, the values differed significantly with the RDA values, p =0.0001, 0.041 and 0.0001 for protein, carbohydrates and iron respectively. The girls did not satisfy the RDA of any of the nutrient.

4.1.5 Nutritional Status of the Respondents

The BMI, MUAC and hemoglobin values of the respondents are shown in Table 4.4.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Geophagic Mean(SD)</th>
<th>Non geophagic Mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anthropometric measurements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.0(9)</td>
<td>58.0(7.2)</td>
<td>0.88</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.6(6)</td>
<td>164.0(5.5)</td>
<td>0.04</td>
</tr>
<tr>
<td>MUAC (cm)</td>
<td>26.5(2.3)</td>
<td>26.3(2)</td>
<td>0.51</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.8(3)</td>
<td>21.5(2.4)</td>
<td>0.26</td>
</tr>
<tr>
<td>Hb (g/dl)</td>
<td>11.7(1.9)</td>
<td>12.11(2)</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Results from an independent sample t –test showed that the mean weight of the respondents in the two groups were not significantly different (p=0.88). However, a significant difference in height was shown(p=0.04). The mean MUAC, BMI and hemoglobin of the two groups did not differ significantly (Table 4.4).
Table 4.5 BMI and Anemia of the Respondents

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Geophagic n=135</th>
<th>Non-geophagic n=167</th>
<th>Total n=302</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n(%)</td>
<td>n(%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18-underweight</td>
<td>21(16)</td>
<td>16(10)</td>
<td>37(12)</td>
<td>0.017</td>
</tr>
<tr>
<td>18-25-normal</td>
<td>95(70)</td>
<td>140(84)</td>
<td>235(78)</td>
<td></td>
</tr>
<tr>
<td>25-30- over weight</td>
<td>19(14)</td>
<td>11(06)</td>
<td>30(10)</td>
<td></td>
</tr>
<tr>
<td>Aneamia classification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hb &lt;12 mg/dl-anemic</td>
<td>60(44)</td>
<td>56(34)</td>
<td>116(38)</td>
<td>0.058</td>
</tr>
<tr>
<td>hb &gt;12 mg/dl-non anemic</td>
<td>75(56)</td>
<td>111(66)</td>
<td>186(62)</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.5 shows the classification of nutrition attributes of the respondents. Most of the respondents 140(84%) in the non geophageous group had normal BMI compared to the geophageous group 95(70%) had normal BMI. Few respondents 21(16%) and 16(10%) in the geophageous and non geophageous groups respectively were underweight. Overweight cases were also few with 19(14%) from the geophageous group and 10(6%) from the non geophageous group. There was a significant difference between the two groups on BMI classification (p=0.017).

Respondents were classified as having anemia if they had a Hb < 12. Sixty (44%) of the geophageous respondents and 56(34%) of the non geophageous respondents were anemic. There was no significant difference between the two groups (p = 0.058). The prevalence of anemia among all the girls was 38%.
4.1.6 Geophageous Characteristics of the Respondents

The geophageous characteristics of the respondents from the two schools are shown in Table 4.6.

Table 4.6: Geophageous Characteristics of the Respondents from the Two Schools.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>St Annes school</th>
<th>Nangili school</th>
<th>Total</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n(%) n=67</td>
<td>n(%) n=68</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Source of soil</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buy from market</td>
<td>22(33)</td>
<td>17(25)</td>
<td>39(29)</td>
<td>0.347</td>
</tr>
<tr>
<td>From ant hill</td>
<td>45(67)</td>
<td>51(75)</td>
<td>96(71)</td>
<td></td>
</tr>
<tr>
<td><strong>Amount eaten/day(g)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-20</td>
<td>26(39)</td>
<td>25(37)</td>
<td>51(38)</td>
<td>0.994</td>
</tr>
<tr>
<td>30-40</td>
<td>27(40)</td>
<td>28(41)</td>
<td>55(41)</td>
<td></td>
</tr>
<tr>
<td>40-50</td>
<td>09(13)</td>
<td>10(15)</td>
<td>19(14)</td>
<td></td>
</tr>
<tr>
<td>&gt;50</td>
<td>05(08)</td>
<td>05(07)</td>
<td>10(07)</td>
<td></td>
</tr>
<tr>
<td><strong>Start time</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before menarche</td>
<td>41(61)</td>
<td>29(43)</td>
<td>70(52)</td>
<td>0.039</td>
</tr>
<tr>
<td>After menarche</td>
<td>26(39)</td>
<td>39(57)</td>
<td>65(48)</td>
<td></td>
</tr>
<tr>
<td><strong>Frequency of eating/day</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once</td>
<td>21(31)</td>
<td>16(24)</td>
<td>37(23)</td>
<td>0.549</td>
</tr>
<tr>
<td>Twice</td>
<td>31(46)</td>
<td>37(54)</td>
<td>68(50)</td>
<td></td>
</tr>
<tr>
<td>3 or more</td>
<td>15(23)</td>
<td>15(22)</td>
<td>30(22)</td>
<td></td>
</tr>
<tr>
<td><strong>Reasons for eating soil</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>58(87)</td>
<td>62(91)</td>
<td>120(89)</td>
<td>0.426</td>
</tr>
<tr>
<td>No</td>
<td>09(13)</td>
<td>06(09)</td>
<td>15(11)</td>
<td></td>
</tr>
<tr>
<td>Hunger</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>14(21)</td>
<td>18(26)</td>
<td>32(24)</td>
<td>0.545</td>
</tr>
<tr>
<td>No</td>
<td>53(79)</td>
<td>50(74)</td>
<td>103(76)</td>
<td></td>
</tr>
<tr>
<td>To avoid nausea/vomiting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>04(06)</td>
<td>03(04)</td>
<td>07(5)</td>
<td>0.718</td>
</tr>
<tr>
<td>No</td>
<td>63(94)</td>
<td>65(96)</td>
<td>128(95)</td>
<td></td>
</tr>
<tr>
<td>Abdominal distress(after eating soil)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>15(22)</td>
<td>15(22)</td>
<td>30(22)</td>
<td>0.999</td>
</tr>
<tr>
<td>No</td>
<td>52(78)</td>
<td>53(78)</td>
<td>105(78)</td>
<td></td>
</tr>
</tbody>
</table>

The respondents from the two schools were compared. There were 67 (45%) and 68(44%) geophagic respondents from St. Anne’s and Nangili school respectively.
Soils eaten by the respondents was either bought or obtained from ant-hills. Majority of respondents 45(67%) from St. Anne’s and 51(75%) from Nangili indicated that the source of their soil was ant hills.

Regarding the amount of soil eaten most respondents 27(40%) and 28 (41%) from St. Anne’s and Nangili respectively ate on average 30-40g of soil in a day. On the frequency of eating soil most respondents from both schools indicated that they ate soil at least twice a day.

Most respondents 41(61%) from St. Anne’s compared to Nangili 29(43%) indicated that they started eating soil before menarche (p = 0.039).

Urge of eating soil was the major reason for the geophagic behavior. More than three quarters of the respondents 58(87%) and 62(91%) from St. Anne’s and Nangili respectively attested to that.

Most of the respondents 52(78%) and 53(78%) from St. Anne’s and Nangili respectively did not experience any abdominal distress after eating soil.

4.1.7 Predictors of Geophagy

The factor that were found significantly associated with geophagy at bivariate analysis were class, mother/guardian geophagic, occupation of the mother/guardian, education of mother/guardian, family size and home setting. The statistics of these predictors as they influence geophagy of the girls are shown in Table 4.7.
Table 4.7 Predictors of Geophagy

<table>
<thead>
<tr>
<th></th>
<th>S.E.</th>
<th>Sig.</th>
<th>Odds ratio</th>
<th>95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>0.114</td>
<td>0.082</td>
<td>0.820</td>
<td>0.655 - 1.026</td>
</tr>
<tr>
<td>Mother geophagy</td>
<td>0.261</td>
<td>0.000</td>
<td>0.357</td>
<td>0.214 - 0.595</td>
</tr>
<tr>
<td>Occupation of mother</td>
<td>0.186</td>
<td>0.826</td>
<td>1.042</td>
<td>0.724 - 1.500</td>
</tr>
<tr>
<td>Education of mother</td>
<td>0.223</td>
<td>0.054</td>
<td>1.538</td>
<td>0.993 - 2.382</td>
</tr>
<tr>
<td>Family size</td>
<td>0.273</td>
<td>0.033</td>
<td>0.558</td>
<td>0.327 - 0.953</td>
</tr>
<tr>
<td>Home setting</td>
<td>0.259</td>
<td>0.168</td>
<td>1.429</td>
<td>0.860 - 2.375</td>
</tr>
<tr>
<td>BMI class</td>
<td>0.267</td>
<td>0.525</td>
<td>0.844</td>
<td>0.501 - 1.423</td>
</tr>
</tbody>
</table>

The variables which were significant after chi-square analysis were entered into a logistic regression model to determine the significant predictors of geophagy.

The significant predictors of geophagy from the regression model were mother/guardian geophagic (p=0.0001, OR =0.357, CI=0.0655-1.026) and family size (p=0.003, OR =0.558, 95%CI =0.327-0.953). Girls from geophagic mothers were 1.36 times more likely to be georphagic than those with non-geophargic mothers. Then, family size influenced geophagy in the girls up to 55.8%

4.1.8 Helminthes ova Infestation of The Soil and Stools Samples

Soil from termite mounds from the two schools and that sold in Nairobi and Kitale open air markets were analyzed for presence of helminthes ova. However, no helminthes ova were discovered in all of the soil samples from the three locations. Stool samples were also taken from the 302 respondents and analyzed but there were no signs of helminthes infestation.
4.1.9 Iron Content of the Soil samples

Soil from termite mounts from the two schools and that sold in Nairobi and Kitale open air markets were analyzed for iron. Results showed highest levels of iron (4.1mg/100g of soil) in soils sold in Nairobi. The soils commonly consumed by the girls had on average 2.5mg/100g of iron, while the one bought from Kitale market contained average of 1.8mg/100g (Table 4.8).

Table 4.8 Iron Content of Soils Samples

<table>
<thead>
<tr>
<th>Source</th>
<th>Iron content (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nairobi</td>
<td>4.1</td>
</tr>
<tr>
<td>Kitale</td>
<td>2.5</td>
</tr>
<tr>
<td>School</td>
<td>1.8</td>
</tr>
</tbody>
</table>

4.2 Product Development

4.2.1 Iron Contents of Ingredients

Table 4.9 shows the seasonal variation in iron content of millet amaranth and termites.

Table 4.9: Seasonal Variation in Iron Content of Millet, Amaranth and Termites

<table>
<thead>
<tr>
<th>Season</th>
<th>Millet</th>
<th>Amaranth</th>
<th>Termites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry (January)</td>
<td>35.1±7.6</td>
<td>37.6±12.5</td>
<td>-</td>
</tr>
<tr>
<td>Long rains (May)</td>
<td>34.2±16.9</td>
<td>23.7±7.4</td>
<td>90.5±10.6</td>
</tr>
<tr>
<td>Short rain (August)</td>
<td>34.4±10.6</td>
<td>31.9±8.7</td>
<td>83.9±2.5</td>
</tr>
</tbody>
</table>

Millet, amaranth and termites were collected from Kakamega, Kitale and Nairobi markets during the dry season, long rains and short rains. The iron contents were analyzed and means computed as in Table 4.9. Termites were not available on the market during the dry season.
4.2.2 Sensory Properties of the Formulations

The sensory attributes of colour, odour, flavor, and texture of the product are shown in Table 4.10.

Table 4.10: Mean Score for Sensory Attributes of the Food Formulations

<table>
<thead>
<tr>
<th>Product</th>
<th>Colour</th>
<th>Odour</th>
<th>Flavour</th>
<th>Texture</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>M70%: A20%: T10%</td>
<td>3.2±0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.6±1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.2±0.79&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.0±1.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.6±1.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>M100%: A0%: T 0%</td>
<td>1.8±0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.6±0.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.0±1.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.8±1.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.0±0.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>M70%: A10%: T20%</td>
<td>5.0±1.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.8±1.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.6±2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.6±0.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.2±1.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>M70%: A15%: T15%</td>
<td>3.6±1.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.4±1.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.4±1.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.8±0.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.6±1.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values in the same column followed by the same letter are significantly different (p>0.05)
M-Millet, A-Amaranth T-Termites

The formulation that showed a high score on preference was the one that contained 70% millet, 20% amaranth and 10% termites. This formulation contained 16.6mg/100g iron and was adopted for the intervention study.

4.2.3 Phytochemical and biochemical composition of the different formulated food.

The biochemical and phytochemical composition of the formulated food is indicated in Table 4.11.

Table 4.11: Phytochemical and biochemical composition of the different formulated food

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates(%)</td>
<td>10.15</td>
</tr>
<tr>
<td>Proteins(%)</td>
<td>6.5</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>3.42</td>
</tr>
<tr>
<td>Fibre (%)</td>
<td>2.7</td>
</tr>
<tr>
<td>Total ash(%)</td>
<td>4.57</td>
</tr>
<tr>
<td>Iron (mg/100g)</td>
<td>16.6</td>
</tr>
<tr>
<td>Phytic acid (mg/100g)</td>
<td>2.4</td>
</tr>
<tr>
<td>Tannins (mg/100g)</td>
<td>41</td>
</tr>
</tbody>
</table>
Proximate analysis of the most preferred formulation showed that it contained 6.5% moisture, 10.15% protein, 4.57% fats, 3.42% fibre, 2.7% total ash, 72.66% carbohydrates and 16.6mg/100g iron.

The mean iron content was 16.6mg/100g. The mean content of the tannins and phytic acid of the preferred formulation were 41mg/100g and 2.4g/100g respectively (Table 4.11).

4.2.4 Shelf-life Evaluation of the Preferred Formulation

Storage quality is an important parameter influencing the utilization potential of food. The inherent composition, environment of storage and packaging material used for packaging determine the shelf life of commodities. It was observed that the storage of the product exhibited no apparent deterioration in the quality in terms of appearance by visual observation and mite/insect infestation.

Peroxide value at the start of the storage was 9.8meq/kg the value reduced during the first two weeks of storage for both storage materials and temperature, however by the end of the fourth week the peroxide value had increased, these increased up to the eighth week and then reduced by the end of the twelfth week (Figure 4.2).
Figure 4.2. Effect of storage on peroxide value
4.3 Intervention

This section presents results of the respondents before and after the intervention was administered. Fifty eighty girls were sampled out and randomly assigned to the treatment group and control group. Each group had 29 respondents.

4.3.1 Characteristics of the Respondents before Intervention

The socio- demographic and geophagic characteristics of the respondents before intervention are presented in Table 4.12.
Table 4.12 General characteristics of the geophagic respondents at baseline

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Treatment group</th>
<th>Control group</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=29</td>
<td>n=29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td><strong>Class</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form 2</td>
<td>13 (45)</td>
<td>14(48)</td>
<td>0.653</td>
</tr>
<tr>
<td>Form 3</td>
<td>10 (34)</td>
<td>07(24)</td>
<td></td>
</tr>
<tr>
<td>Form 4</td>
<td>06 (21)</td>
<td>08(28)</td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13- 15</td>
<td>09 (31)</td>
<td>07 (24)</td>
<td>0.557</td>
</tr>
<tr>
<td>16-18</td>
<td>20 (69)</td>
<td>22 (76)</td>
<td></td>
</tr>
<tr>
<td><strong>Mother/guardian geophagic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>19 (66)</td>
<td>18 (62)</td>
<td>0.785</td>
</tr>
<tr>
<td>No</td>
<td>10 (34)</td>
<td>11 (38)</td>
<td></td>
</tr>
<tr>
<td><strong>Education level of mother/ guardian</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>05 (17)</td>
<td>06 (21)</td>
<td>0.497</td>
</tr>
<tr>
<td>Secondary</td>
<td>12 (42)</td>
<td>12 (41)</td>
<td></td>
</tr>
<tr>
<td>Certificate/diploma</td>
<td>07 (24)</td>
<td>03 (10)</td>
<td></td>
</tr>
<tr>
<td>Graduate</td>
<td>05 (17)</td>
<td>08 (28)</td>
<td></td>
</tr>
<tr>
<td><strong>Beginning of geophagy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before menarche</td>
<td>19 (66)</td>
<td>17 (59)</td>
<td>0.588</td>
</tr>
<tr>
<td>After menarche</td>
<td>10 (34)</td>
<td>12 (41)</td>
<td></td>
</tr>
<tr>
<td><strong>Source of soil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supermarket</td>
<td>04 (14)</td>
<td>-</td>
<td>0.064</td>
</tr>
<tr>
<td>From open air market</td>
<td>06 (21)</td>
<td>11 (38)</td>
<td></td>
</tr>
<tr>
<td>Termite mount</td>
<td>19 (65)</td>
<td>18 (62)</td>
<td></td>
</tr>
<tr>
<td><strong>Amount of soil eaten/day</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-20g</td>
<td>11 (38)</td>
<td>04 (14)</td>
<td>0.066</td>
</tr>
<tr>
<td>30- 40g</td>
<td>09 (31)</td>
<td>07 (24)</td>
<td></td>
</tr>
<tr>
<td>40-50g</td>
<td>04 (14)</td>
<td>05 (17)</td>
<td></td>
</tr>
<tr>
<td>&gt;50g</td>
<td>05 (17)</td>
<td>13 (45)</td>
<td></td>
</tr>
<tr>
<td><strong>Frequency of eating soil/day</strong></td>
<td></td>
<td></td>
<td>0.378</td>
</tr>
<tr>
<td>Once</td>
<td>06 (21)</td>
<td>06 (21)</td>
<td></td>
</tr>
<tr>
<td>Twice</td>
<td>09 (31)</td>
<td>04 (14)</td>
<td></td>
</tr>
<tr>
<td>Thrice</td>
<td>11 (38)</td>
<td>13 (44)</td>
<td></td>
</tr>
<tr>
<td>&gt;thrice</td>
<td>03 (10)</td>
<td>06 (21)</td>
<td></td>
</tr>
<tr>
<td><strong>Reasons for eating soil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel the urge of eating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>26 (90)</td>
<td>27 (93)</td>
<td>0.640</td>
</tr>
<tr>
<td>No</td>
<td>03 (10)</td>
<td>02 (07)</td>
<td></td>
</tr>
<tr>
<td>Avoid vomiting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>02 (07)</td>
<td>01 (03)</td>
<td>0.999</td>
</tr>
<tr>
<td>No</td>
<td>27 (93)</td>
<td>28 (97)</td>
<td></td>
</tr>
<tr>
<td>Hunger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>02 (07)</td>
<td>-</td>
<td>0.491</td>
</tr>
<tr>
<td>No</td>
<td>27(93)</td>
<td>29 (100)</td>
<td></td>
</tr>
<tr>
<td>Abdominal distress(after eating soil)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>05 (17)</td>
<td>12 (41)</td>
<td>0.082</td>
</tr>
<tr>
<td>No</td>
<td>24 (83)</td>
<td>17 (59)</td>
<td></td>
</tr>
</tbody>
</table>
As shown in Table 4.12 there was no significant difference (p > 0.05) between the treatment group and control group on the general characteristics of the subjects before the intervention. Most of the girls who volunteered to participate in the study were in form two class 13 (45%) in treatment and 14 (48%) in the control group. The age distribution of the subjects was between 13 – 18 years with almost three quarters 20 (69%) in the treatment and 22 (76 %) in the control groups falling in the age range of 16 – 18 years. More than half of the subjects both in the treatment group 19 (65%) and control group 18 (62%) indicated that their mothers/ guardians are geophagic. Most of the respondents 12(41%) both in the treatment and control groups indicated that their parents had attained secondary level education. More than half of the subjects both in the treatment 19 (66%) and control 17 (59%) group began eating soil at an early age before menarche.

The source of soil eaten was either the supermarket, open air market or termite mounts. Almost two thirds of the respondent 19 (66%) in the treatment group and 18 (62%) in the control group obtained their soil from termite mounts. On average the respondents consume 30-40g of soil in a day with most of the eating it thrice in a day.

The major reason for eating soil was craving for the soil which was increased by the taste and colour. Only 2 (7%) in the treatment group indicated that they ate soil because of hunger. Although some respondents admitted that the behavior causes them abdominal distress, majority 24(83%) in the treatment and 17 (59%) in the control group had no problem with the practice.
4.3.2. Nutritional characteristics of Geophagic Respondents before and after Intervention.

Table 4.13 shows the anthropometric parameters of the respondents before and after intervention

**Table 4.13 Anthropometric and Measurement of Geophagic Respondents Before and After Intervention**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Treatment Mean (SD)</th>
<th>Control Mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before intervention</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.1 (7)</td>
<td>58.3 (10)</td>
<td>0.95</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.8 (6)</td>
<td>162.9 (6)</td>
<td>0.61</td>
</tr>
<tr>
<td>MUAC (cm)</td>
<td>27.4 (2)</td>
<td>27.1 (2.7)</td>
<td>0.69</td>
</tr>
<tr>
<td>BMI (Kg/m²)</td>
<td>21.7 (2.6)</td>
<td>21.8 (3)</td>
<td>0.93</td>
</tr>
<tr>
<td><strong>After intervention</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>57.7 (6.7)</td>
<td>58.6 (10.7)</td>
<td>0.71</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.7 (6.1)</td>
<td>162.5 (5.7)</td>
<td>0.46</td>
</tr>
<tr>
<td>MUAC (cm)</td>
<td>26.2 (2.6)</td>
<td>26.5 (2.3)</td>
<td>0.71</td>
</tr>
<tr>
<td>BMI (Kg/m²)</td>
<td>21.5 (2.7)</td>
<td>22.1 (3.4)</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Mean height and body weight for the treatment and control subjects was 163.8 ± 6 cm, 162.9 ± 6 cm, 58.1 ± 7 kg and 58.3 ± 10 kg respectively. These values were not significantly different between the groups (p < 0.05).

The mean MUAC was 27.4 ± 2 and 27.1 ± 2.7 for the treatment and control group respectively, with no significant difference between the means (p = 0.694, t =0.395). The mean body mass index of the subjects was normal 21.7 ± 2.6 for the treatment group and 21.8 ± 3 for the control group. After intervention Table 4.13 shows that the anthropometric characteristics of the respondents did not differ significantly (p < 0.05) between the treatment and control groups on anthropometric measurements (weight, height, MUAC, and BMI).
4.3.3 Hematological Profiles before and after Intervention

The hematological parameters of Hemoglobin, Hct and Mean corpuscular volume of the respondents before and after intervention are presented in Table 4.14.

### Table 4.14: Hematological Characteristics of the Geophagic Respondents Before and After Intervention

<table>
<thead>
<tr>
<th>Hematological measurements</th>
<th>Treatment Mean (SD)</th>
<th>Control Mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before intervention</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>11.76 (2.1)</td>
<td>12.2 (1.7)</td>
<td>0.367</td>
</tr>
<tr>
<td>Hematocrit ratio Hct (%)</td>
<td>38.1 (6.7)</td>
<td>40.1 (3.8)</td>
<td>0.167</td>
</tr>
<tr>
<td>Mean corpuscular volume (fL)</td>
<td>84.2 (11.1)</td>
<td>80.4 (11.3)</td>
<td>0.206</td>
</tr>
<tr>
<td><strong>After intervention</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>12.76 (1.3)</td>
<td>12.01 (1.3)</td>
<td>0.035</td>
</tr>
<tr>
<td>Hematocrit ratio HCT</td>
<td>40.8 (3.1)</td>
<td>39.1 (2.8)</td>
<td>0.034</td>
</tr>
<tr>
<td>Mean corpuscular volume (MVC)</td>
<td>85.3 (9.5)</td>
<td>82.2 (7.1)</td>
<td>0.189</td>
</tr>
</tbody>
</table>

The mean hemoglobin for the treatment group was 11.76 ± 2.1 g/dL an indication of anemia. The mean hemoglobin for the control group was marginal 12.2 ± 1.7 g/dL however, there was no significant difference between the means (p = 0.367). The mean hematocrit values for both groups (38.1±6.7 for treatment and 40.1±3.8 for control) fell under the normal category.

After intervention Table 4.12 shows that the mean hemoglobin value for the treatment (12.76±1.3 g/dl) was higher than that of the control group (12.01±1.3 g/dl), this showed a significant difference (p = 0.035). The hematocrit ratio of the treatment group (40.8±3.1) also differed significantly (p =0.034) from that of the control group (39.1±2.8). The effect size ($d$) of both hemoglobin and hematocrit values was 0.6. The Mean corpuscular volume of the two groups did not differ significant (p = 0.174).
4.3.4 Geophagic Characteristics after Intervention

Table 4.15 shows the geophagic behavior of the respondents after intervention.

Table 4.15: Geophagic characteristics after intervention.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Treatment group</th>
<th>Control group</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n= 28 n(%)</td>
<td>n= 27 n(%)</td>
<td></td>
</tr>
<tr>
<td>Geophagy</td>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>Yes</td>
<td>01(04)</td>
<td>22(82)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>27(96)</td>
<td>05(18)</td>
<td></td>
</tr>
<tr>
<td>Urge of geophagy</td>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>Yes</td>
<td>06(21)</td>
<td>24(89)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>22(79)</td>
<td>03(11)</td>
<td></td>
</tr>
</tbody>
</table>

Out of the 58 participants that were enrolled in the trial only 55 (95%) completed the study (28 in the treatment group and 27 in the control group). Three respondents (two controls, one treatment) dropped out of the study, the two from control dropped out of school and the one in the treatment group developed sensitivity to the intervention product and therefore was discontinued.

After administering the snack for eight weeks to the treatment group, only one respondent indicated that she was still eating soil, however, 6(21%) indicated that they still had the urge of eating soil. Twenty two (81%) of the respondents in the control group were eating soil at the end of the intervention period, however, 24(89%) reported to have the urge of eating soil. There was a significant difference between the treatment group and the control group (p = 0.001) on geophagic behavior at the end of the intervention period as shown in Table 4.15).

4.3.5 Change of the Nutritional and Heamatological Parameters during start of Intervention for the Treatment and Control groups

Table 4.16 shows the change in the nutritional and hematological characteristics of the respondents in the treatment group and control group.
Table 4.16 Change of nutritional parameters during intervention

<table>
<thead>
<tr>
<th>Attribute</th>
<th>End of intervention</th>
<th>Start of intervention</th>
<th>change</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Treatment group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Anthropometric</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>57.7(6.7)</td>
<td>58.3(7.1)</td>
<td>-0.64(3.7)</td>
<td>0.377</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.7(6.1)</td>
<td>163.7(6.1)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MUAC (cm)</td>
<td>26.2(2.6)</td>
<td>26.5(2.0)</td>
<td>-0.26(1.4)</td>
<td>0.336</td>
</tr>
<tr>
<td>BMI(Kg/m²)</td>
<td>21.5(2.7)</td>
<td>21.8(2.6)</td>
<td>-0.27(1.5)</td>
<td>0.346</td>
</tr>
<tr>
<td></td>
<td><strong>Haematological</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemoglobin(g/dL)</td>
<td>12.76(1.3)</td>
<td>11.69(2.1)</td>
<td>1.1(1.7)</td>
<td>0.001</td>
</tr>
<tr>
<td>Hematocrit ratio</td>
<td>40.8(3.1)</td>
<td>38.74(4.8)</td>
<td>2.1(3.2)</td>
<td>0.002</td>
</tr>
<tr>
<td>Mean Corpuscular</td>
<td>85.26(9.5)</td>
<td>83.8(11.1)</td>
<td>1.5(3.2)</td>
<td>0.022</td>
</tr>
<tr>
<td>Volume(FL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Control group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Anthropometric</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.6(10.7)</td>
<td>58.3(10)</td>
<td>0.24(3.5)</td>
<td>0.726</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.5(5.7)</td>
<td>162.9(6)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MUAC (cm)</td>
<td>26.5 (2.3)</td>
<td>27.1(2.7)</td>
<td>0.08(0.9)</td>
<td>0.626</td>
</tr>
<tr>
<td>BMI(Kg/m²)</td>
<td>22.1 (3.4)</td>
<td>21.8 (3)</td>
<td>0.24(1.2)</td>
<td>0.322</td>
</tr>
<tr>
<td></td>
<td><strong>Haematological</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemoglobin(g/dL)</td>
<td>12.01(1.3)</td>
<td>12.2(1.7)</td>
<td>-0.176(1.9)</td>
<td>0.632</td>
</tr>
<tr>
<td>Hematocrit ratio</td>
<td>39.1(2.8)</td>
<td>40.1(3.8)</td>
<td>-1.04(4.4)</td>
<td>0.226</td>
</tr>
<tr>
<td>Mean corpuscular</td>
<td>82.2(7.1)</td>
<td>80.4(11.3)</td>
<td>0.24(1.7)</td>
<td>0.467</td>
</tr>
<tr>
<td>volume(FL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A paired sample t-test showed no significant difference between the anthropometric characteristics of respondents at the start of the intervention and at the end of the intervention for both the treatment and control group (p < 0.05) (Table 4.16).

The mean hemoglobin, hematocrit ratio and mean corpuscular volume change for the treatment group was 1.1±1.7g/dl, 2.1±3.2g/dl and 1.5±3.2 respectively the changes were significant (p= 0.001, t =4.34; p = 0.002 t= 3.397; p = 0.022 t = 2.431). The magnitude (effect size = d) of difference between the hematological parameters of the treatment group were 0.61, 0.54 and 0.14 for hemoglobin, hematocrit ratio and Mean Corpuscular Volume respectively.
The hematological parameters of the control group showed no significant change at the end of the intervention ($p > 0.05$) (Table 4.16).
CHAPTER FIVE: DISCUSSION

5.0 Introduction

In this chapter, the findings of the study are discussed and compared with findings from other studies. The study explored the relationship between geophagy and anemia and sought to find a solution to geophagy through a food based intervention. The discussion has been organized based on findings at baseline survey, product development and intervention study.

5.1 Baseline

5.1.1 Prevalence of Geophagy and Diversity of Soils Eaten

Clay eating is widespread among women in Africa but in particular five African countries namely Malawi, Zambia, Zimbabwe, Swaziland and South Africa, where an estimated prevalence level in the rural areas are up to 90% (Walker et al., 1997).

In this study 45% of the respondents were geophagic. It is important however to note that this group represented only a segment of the women population unlike the previous studies which involved basically all women within the reproductive age bracket. But there are other relevant studies which still report higher prevalence. For example, Geisler et al. (1998) reported 73% among adolescents aged 11-18 and George and Ndip (2011) reported 75% among women of age 20-60 in South Africa.

In this study the prevalence of geophagy was not found to be significantly different among rural and urban dwellers at 52% and 48% respectively. Walker et al., (1997) reported prevalence of pica among urban and rural black South African women at 38.3 and 44.0% respectively. This indicates that the practice of geophagy is independent of their abode. Other studies (Anell and Lagercrantz, 1958; Cooper, 1957 and Laufer, 1930) also report that the phenomenon of geophagy is not restricted to age group, race, sex, or geographic region. The
frequency of consumption varied from more than once daily to occasionally, as reported by George and Ndip (2011) among women in South Africa.

Gilardi et al., (1999) noted that there are preferred soils in geophagy, but that several soil types are consumed. These include red, white, yellow, brown clay and termite. The reported sources and location of geophagic soils in this study included hill/mountain, termite mounds this was consistent with George and Ndip (2011). Soils from termite mounts may have been preferred because of the characteristic taste and smell which attracts most women who eat soil. Moreover the soil is found at no cost. In this study, the respondents had no choice since soil from termite mounts is the only type available in the school setting. The average amounts of soil eaten ranged between 30-40g per day, results which are consistent with other studies which reported average of 30-50g per day in Kenya and Zanzibar (Geisler et.al. 1997, Luoba et al., 2005; Young et.al., 2010).

5.1.2 Geophagy and Helminthes Infestation.

Several studies have linked geohelminths infestation with soil consumption. Geohelminths infection was linked to iron-deficiency among HIV-infected women who indulge in geophagia (Kawai et al., 2009). Studies on geophagous children in Jamaica (Wong et al., 1991) and Kenya (Geissler et al., 1998) reportedly gave a quantitative estimate of the levels of exposure to intestinal *A. lumbricoides* and *T. trichiura* infestation experienced by the children. The highlights of the study conducted by Saathoff et al. (2002) were the social pattern of geophagia and its possible role in the transmission of *A. lumbricoides, T. trichiura* and hookworm in a rural area of South Africa. However, according to Gelfand (1945) and Heyman (2004), there is little evidence to support the transmission of hookworms by geophagy. In this study, results showed no viable helminthes ova in the geophagic soils tested. These results are consistent with results by Young et al. (2007).
In other studies (Wong et al., 1991; and Geissler et al., 1998a and Robinson et al., 1990) viable helminthies were discovered in geophagic soils. The difference was explained by Young et al. (2007) that the latter was conducted on soils eaten by children who may have been more careless than adults about selection and preparation of the soil before consuming. In the present study, the soils were picked from selected sites, but no form of preparation of soil before eating was reported. Therefore the absence of helminthes in the geophagic soils in this study may be attributed to sanitary sources of the soil and the handling of the soil before consumption.

5.1.3 Prevalence of Anemia among the respondent girls

The prevalence of anemia among the girls in this study was 38%. However, Leenstra et al., 2004 in a study among adolescent girls in Nyanza found prevalence of anemia (Hb <120 g/L) of 21.1%, much lower than the status found in this study. Similarly, studies on prevalence of anemia from different states of rural India, reported high prevalence of anemia from 46-98% (Kanani, 1994), Sindhu et al. (2005) in a study carried out among 265 adolescent girls of Amritsar also discovered high prevalence of 70-75% of anemia including 12.83% girls with severe anemia. The prevalence of anaemia in this study was higher than the prevalence reported by Sayes et al., (2010) and by WHO of 27% for developing countries (WHO, 2005)

The high prevalence of anemia in this study may be attributed to the diet of respondents which was lacking fruits and the frequency of meat intake was low. Kales were constant components of the meals but these were boiled during preparation for cooking and the water discarded, so that it is possible they lost much iron through leaching. In addition, some of the vitamin C component may have been destroyed yet vitamin C is important in enhancing absorption of iron from foods. This could have played a big role in the high prevalence of anemia among the girls. Dietary factors such as low consumption of red meat, vegetables,
cereals and fruits have been reported to be associated with iron deficiency anemia (Galan et al., 1998). Heme iron (from meat) should provide 10 to 20% of iron intake while non-heme iron (from vegetables, fruits, and cereals) provides 80 to 90%. In this study girls were eating meat only twice a week.

Non-heme iron absorption is poor and is influenced by the iron status of subjects and the balance between enhancers and inhibitors present in the food, much more than heme iron (Tseng et al., 1997). Other study revealed similar results that female subjects infrequently consuming red meat and vegetables (less than two servings of red meat and vegetables per week) were at increased risk to develop ID and IDA (Al-Quaiz, 2001). According to WHO (2001) iron deficiency anaemia would be considered a public health problem only when the prevalence of low hemoglobin concentration exceeds 5.0% of the population. Therefore the prevalence in this study indicates a public health problem.

Geophagy has long been associated with iron deficiency, but evidence for cause or effect is controversial (Parry & Parry, 1992). In this study anemia was not significantly associated with geophagy. In a study in rural Kwa Zulu Natal by Hoque et al., (2007) geophagic practices were not considered a cause of anaemia among pregnant women. According to Bisi et al.,(2010), anemia resulting from geophagia is believed, in some cases, to have resulted from the worm infestation or microbial infection detected.

5.1.4 Predictors of Geophagy

In this study hemoglobin concentration was not significantly higher in geophagic girls compared to the non geophagic girls (p> 0.05) this is not consistent with Geisler et al., 1998. This showed that hemoglobin concentration was not predictor of geophagy. In this study 70(52%) of the geophagic girls started the practice before menarche. The fact that some girls started the practice after menarche shows that low hemoglobin levels associated with
menestration would have triggered the practice. Research has shown that the historical origin of geophagy may be originally tied to biological drives triggered by vital minerals in the substances being consumed (Forsyth 1988). Still, in interviews with practitioners, many scholars have found that its contemporary practice seems to be the result of nurture, not nature (Forsyth 1988). Their responses seem to indicate that instead of fulfilling nutritional needs, geophagy is being practiced for psychosomatic reasons. Study by Frate (1984) supports this notion. He concluded that young children pick up the habit from their mothers, who consider soil a convenient pacifier. In this study more than half 82 (60%) of the geophageous girls indicated that their mothers/guardians were geophageous. Forsyth (1988) in his study concluded that very few of the clay eaters acquired the taste without the influence of other individuals. Bisi et al., (2010) also observed that the practice amongst many of the kaolin eaters emanated from having watched their mothers or close relations eat the clay.

In other studies, pregnant women interviewed by Johns(1991) and Vermeer (1966) said they were "taught" to eat clay because it settles the stomach and reduces the nausea and vomiting associated with morning sickness. In this study most respondents did not eat soil to avoid nausea or vomiting but a few attested to that. In a study conducted by Hunter (1973), people said that they ate earth because it tastes good indicating craving as a reason of eating soil, this was consistent with Forsyth (1988), the two studies show consistent results with this study where urge of eating soil was the major reason for the geophagic behavior. Hunger was not a major reason for eating soil, less than 25% of the respondents indicated it. Although hunger was not a major reason for eating soil in this study, 32 (24%) indicated that hunger makes them eat the soil. This was consistent with Young et al. (2010). The researchers compiled reports of 72 cultural studies on geophagy. Geophagy was attributed solely on hunger in only 16(22%) of the reports. Hunger was explicitly not associated with geophagy in 36 reports (50%). If hunger motivated geophagy we would expect that enough soil would be eaten to fill
the geophagist’s stomach. Since the amount of soil eaten per day is small it’s more like a medicament than a meal.

5.2.0 Product Development

In this study a soil replacer was developed from millet, amaranth grains and termites and given as an intervention for geophagy. Millet based food formulations have been developed by other researchers for intervention in various health conditions. Although no study has developed a formulation for interventions towards geophagy, there are several aspects that can be compared.

5.2.1 Iron Content of the Formulation Ingredients

Finger millet is usually used for preparation of flour, pudding, porridge and roti (Chaturvedi et al., 2008). With the changes in scenario of utilization pattern of processed products and awareness of the consumers about the health benefits, finger millet has gained importance because of its functional components, such as slowly digestible starch and resistant starch (Wadikar et al., 2007). A study done in India documented variation in nutrient content of two varieties of finger millet (ragi, and kodo), ragi millet was nutritionally superior compared to kodo. Ragi millet contained more fibre, more mineral and more vitamins.

The iron content for ragi and kodo was 6.3 and 5.0mg/100g respectively. In the present study a variation in iron content was observed. The variation was based on locality and season when the millet was purchased. Values of between 17.5mg/100 – 51.2 mg/100g of iron in the finger millet were recorded.

Insects have played an important role in the history of human nutrition and it is probable that the first hominids in African were eating insects. Insects including termites are good sources of protein with high fat content (and thus energy) and many important minerals and vitamins (Banjo et al., 2006). In a study in Western Kenya, it was established that termites were
widely consumed, among the communities with distinct availability seasons associated with long and short rains. They are available in local markets when in season and harvesting is easily done when in and out of season (Kinyuru et al., 2009). Use of edible insects as a novel ingredient in conventional food products has been documented. Kinyuru et al., (2009) developed baked wheat-termite buns with a significant portion of the ingredients being edible termites while other varied products have been developed by Ayieko et al., (2010).

Most geophagist reported to eat soil from termite mounts, this study utilized termites so that in case there is any compound in termites that make them prefer the soil from the termite mounts then the advantage is utilized. Moreover termites are a rich source of iron.

A study in Niger documented iron content of between 52.43-56.09 mg/kg in termites (Ntukuyoh et al., 2012). In another study on nutrient composition of tamandua termites in Venezuela it was found that Iron (Fe) values were the highest among the trace minerals but highly variable. The concentration of this element in the soldier caste (100.1 mg/100g) was two times higher than Fe content in workers (39.4 mg/100g) (Sergio et al., 1996).

Paoletti et al. (2003) also noted large amounts of iron in both the termite thorax and abdomen (868 ug/g) and heads (1090 ug/g) this was described to be very high, 10 times more than any other conventional meat. A study in western Kenya revealed that winged termites (M. subhylanus) had the highest iron content (21mg/100g) among the animal source foods (Kinyuru et al 2009). In the current study termites were bought from different markets and in different seasons, analysis showed high iron content of between 82.1mg/100g to 98mg/100g showing slight variations. The variations in this study may be attributed to the difference in species depending on the season. During the long rains of May –July the termites found on the markets were markably larger in size compared to the ones sold during August to December.
In Kenya, amaranth is sold in some supermarkets in major towns, but in very small quantities. Its consumption is also reported in some important institutions like Kenyatta National Hospital in the private wings and in HIV/AIDS orphaned children’s homes, where it is recommended for patients on special diet. Despite its high nutritional value for both human beings and domesticated animals, not many people know about it. There is need to educate people about this important indigenous food and to develop products that can reach a larger population. Amaranth-based porridge has also been adopted for the feeding of normal children as a complementary food, and for feeding the sick including people living with HIV and AIDS (PLWHA).

A study by Mburu et al., (2011) documented 5.2±0.2mg/100g of iron in amaranth grains. Kinyuru et al. (2009) reported an iron content of 21mg/100g. In this the amount of iron in amaranth varied with location and season with the highest recorded as 48.7mg/100g and the lowest 18mg/100g.

Millet based mixes have been developed by several other researchers for different groups. Proso-millet based convenience mix for infants and children was developed by Srivastava et al. (2001) in India. The convenience mix (100g) provided 14.32 g protein, 82.48 mg calcium, 4.20 mg iron, 8.84 mg ascorbic acid and 63.90 mg b-carotene per 50 g of the mix. Sweet and salt gruels, halwa, burfi and biscuits based on the convenience mix were reported to be organoleptically acceptable. In this study the mix developed provided a higher content of iron.

Barnyard and finger millet based khichadi, laddu and baati were prepared along with legumes and fenugreek seeds by Arora and Srivastava (2002) for diabetic patients. Khichadi was prepared with millet, whole green gram and fenugreek seeds in a ratio of 60: 20: 20 respectively. Laddu contained millet, roasted soybean and malted fenugreek seeds in the
proportion of 65: 10: 20 along with 5 per cent popped amaranth seeds. Millet based baati was prepared with millet, fenugreek seed powder and roasted Bengal gram flour in the ratio of 60:20:20. All the products were acceptable.

Veena et al. (2004) explored the substitution of Barnyard millet in five cereal based traditional foods viz., rice, roti, dosa, idli and chakli. These were prepared by different cooking methods like boiling, pan-baking, fermentation, shallow and deep fat frying. The main ingredient of the selected food (except for cooked rice) was substituted with Barnyard millet flour in varying levels of 0, 25, 50, 75 or 100 per cent. It was reported that the substitution improved the nutrients per serving in terms of dietary fibre and minerals but reduced the calorific value. It was suggested that Barnyard millet could be used in most common cereal based traditional foods.

Begum et al. (2003) carried out experiments on nutritional enhancement of common convenience foods such as papads by substituting conventional grains with nutritious millets. Acceptable papads were formulated using Finger millet (60%), sago (20%), black gram (20%) and spices.

Finger millet based pasta products with good cooking quality, storage stability, acceptability and higher nutritive values were developed by Devaraju et al. (2003). Composite finger millet flour (50%), refined wheat flour (40%), defatted soy/whey protein concentrate (10%), and hot water (75°C) were used for pasta making. The mean protein, energy, calcium and iron in the experimental pasta ranged from 14-18 g, 365-372 k cal, 102-148 mg and 3-5 mg respectively. Hima et al., (2003) prepared common Indian traditional products namely muruku, chegodi, dosa, chapathi, laddu and payasam by incorporating Foxtail millet. All the products were acceptable.

Barnyard and Kodo millet based chapathi and dosa and two commercial products viz., noodles and rusk were developed by Poongodi et al. (2003). Millet along with wheat flour
and defatted soy flour in varying proportions were used. The acceptable levels of incorporation of millet flour were reported to be 20% for noodles and 30 per cent for rusk, *chapathi* and *dosai*.

Shanthi et al. (2005) studied on the effect of incorporation of Finger millet in pasta products. Refined wheat flour, whole wheat flour and soya flour were blended with finger millet in different proportions, with wheat and refined wheat flour as the main ingredient. Sensory evaluation revealed that incorporation of Finger millet up to 30% and soya flour up to 10 per cent was acceptable. Thus, the literature reveals that the millets offer wide range of opportunities for utilization in diversified products along with better nutritional qualities.

### 5.2.2 Anti nutrient Factors in Millet based Foods

Phytic acid, myo-inositol 1,2,3,4,5,6-hexakis (dihydrogenphosphate), is the main phosphorus store in mature seeds. Phytic acid has a strong binding capacity. It readily forms complexes with multivalent cations and proteins (Haug and Lantzsch, 1983). This study found out that the content of phytic acid in the millet based product formulated for the intervention was 41 mg/100g. Phytate content in finger millet as observed by various authors has been found to be in range 0.679 to 0.693 mg/100g (Antony and Chandra, 1999). Finger millet has been found to contain 41% phytic phosphorus as percentage of total phosphorus (Deosthale, 2002). Rao (1994) reported phytate content to be 149 to 150 mg/100g in finger millet grains. The dietary phytic acid binds not only with the seed derived minerals but also with other endogenous minerals encountered in the digestive tract (Raboy, 2000).

Among millets finger millets have been reported to contain high amounts of tannins ranging from 0.04 to 3.74% of catechin equivalents (Antony and Chandra, 1999). Rao and Prabhavati (1982) have reported 360 mg/100g tannins in brown finger millet. They also found that 50% of the iron present in the diet might be bound to tannins. This study reported
a tannin content of 2.4mg/100g; this value is significantly lower than the one reported by Rao and Prabhavati (1982). This may also be attributed to the processing techniques used. Processing techniques like soaking, roasting, boiling, germination and fermentation have been found to reduce tannin content (Rao and Prabhavathi, 1982).

There was no effect of storage on the sensory quality of the product. These results are consistent with the Foxtail and Little millet based mix suitable for diabetics, which did not reveal any apparent effects of storage in sensory quality when stored for six months in two different packaging materials (Itagi, 2003). In this study, storage of the food product in polythene bags at two storage temperatures (25°C and 35°C) showed higher accumulation of peroxide compared to storage in Kraft paper in similar conditions. This shows that polythene bags are not good storage material for this food product. This is consistent with Kaced et al., (1984) who demonstrated that millet meal stored in polythene bags turned rancid due to increased peroxide value than in that stored in cotton bag. However, moisture uptake by food stored in polythene bags at both storage temperatures was lower compared to moisture uptake by the food stored in Kraft paper in similar conditions. The food product is likely to have a better shelf life when stored in Kraft paper bags at room temperature (25°C).

5.3.0 Intervention

Most interventions to geophagy have been through iron supplementation. However, minimal reported success has been achieved.

5.3.1 Efficacy of Millet based Products in Management of Geophagy

In this study, after dietary intervention, the mean Hemoglobin concentration had an effect change slightly lower than that by ICRW &IHMP,( 2001) in India. Studies on iron supplementation on geophagy showed no correlation between iron status and geophagy. In a study by Gutelius et al.(1962), no correlation was found between change in pica and change
in hemoglobin concentration. In another study (Nchito et al., 2004) which focused specifically on geophagy, neither randomization to 10 month of iron supplementation nor to 10-month multivitamin significantly reduced geophagy among 402 Zambian schoolchildren. Based on multivariate logistic regression models the authors concluded that iron supplementation and multi-micronutrient supplementation were not significant predictors of geophagy ($p = 0.44$ and $p = 0.88$ respectively). These experimental studies do not support the hypothesis that changes in iron status alter geophagic behavior.

The results of this study at the baseline are consistent with the fact that hemoglobin concentration was not a predictor of geophagy. However, after the intervention study, there was marked increase in hemoglobin level with a remarkable reduction in the geophagic behavior. In this study after the intervention period some girls in the control group stopped eating soil. This indicates that eating of soil is behavioral and can be stopped. Although 96% of the girls in the treatment group had stopped eating soil, 21% were still fighting with the urge to eat. Urge was one of the main reasons for eating soil in this study and other studies. What triggers the urge is the question to be answered.
CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

There was a high prevalence of geophagy among adolescent girls in the two schools.

The predictors of geophagy were family size and mothers or guardians who practice geophagy.

Although it is speculated that anemia is a predictor of geophagy, there was no relationship between geophagy and anemia.

In areas where proper hygiene is practiced, geophagy may not be a risk factor of helminthes infestation.

Geophagy is a learnt behavior and not associated with nutrient deficiencies.

The product formulated was acceptable and the girls greed to use it as a replacer for geophagy.

Traditional foods can be useful in making pseudo food substitutes.

The prevalence of geophagy can be reduced by giving a food substitute to soil.

Hemoglobin levels of the girls increased upon using the food product.

The prevalence of anemia among adolescent girls was higher than that reported by WHO in developing countries and that documented by other studies in the same region.
6.2 Recommendations

Further research to be done to determine the association between geophagy and anemia where serum ferittin could be determined since there is still controversy over the relationship.

The ministry of health in collaboration with food manufacturers should develop a program for commercial production of the soil replacer at community level or industrial level in order to offer food alternative, which will not only help stop the practice but also supply essential nutrients to the users.
REFERENCES


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APPENDICES

APPENDIX I

CONSENT FORM FOR BASELINE SURVEY

STUDY TITLE: DEVELOPMENT AND UTILIZATION OF A FOOD REPLACER FOR GEOPHAGIC ADOLESCENT GIRLS.

I would like to invite you to take part in a research study. Before you decide you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Talk to others about the study if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Introduction

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Eating soil can also physically damage the intestinal mucosa and reduce ability to absorb nutrients. Soil can also effectively bind and remove nutrients that were already present in diet particularly iron and zinc. Soil often contains high levels of aluminium and a study showed that aluminium could reduce serum ferritin and deplete iron stores. Anemia, whether or not the primary cause is iron deficiency, is generally recognized as the main nutritional problem in adolescents. Adverse effects of anemia range from severe morbidity to decreased physical work capacity to deficits in cognitive development and potentially school performance. Iron deficiency may alter cognitive function in children and even in adolescents and the effects may be only partly reversible in severe and prolonged deficiency. The relationship of geophagy with iron status and anaemia is still obscure, it has not been clearly elucidate
whether it is geophagy that causes iron deficiency, or it is iron deficiency that causes geophagy, so that even when adequate nutrients are ingested, there will be apparent deficiencies.

Early intervention is particularly critical in adolescent girls whose nutritional status is marginal to begin with, so that they enter their first pregnancy in a better nutritional state.

**Objectives of the study**

1. To establish the baseline characteristics of adolescent girls with geophagy.
2. To identify the predictors of geophagy among adolescent girls
3. To formulate a product rich in iron from millet, amaranth and termites and feeding of the product to the girls as a replacer for geophagy.
4. To determine the iron content of the foods and formulations
5. To determine the Hemoglobin status of geophagy adolescent girls.

**Recruitment of participants**

A sample of 302 girls will be proportionately drawn from Nangili and St. Annes’. Fifty one percent (154 girls) of the sample will be drawn from Moi girls Nangili while 49% (148 girls) will come from St Annes’. The researcher after consultation with the administrators of the two schools will have sessions with all the girls in the two schools in their schools. The sessions will be done per class. The researcher will introduce the research issue to the students.

The background, purpose of the study, voluntary participation, eligibility and randomization during the recruitment will be highlight during the sessions. After the session, those willing to participate will remain in the room as others leave. The remaining girls will be given numbers and the numbers recorded against their names. This will be repeated for all the four classes. Then using the random number tables a proportionate sample will be drawn from each class.
based on the population of the class. A statistician will determine the allocation sequence and carry out the randomization process.

**Study procedures**

Participants will be expected to fill a questionnaire. Height, weight and mid upper arm circumference of the participants will be taken. The participants will be in light clothes, remove shoes and scarves as the measurements are taken. Height will be measured to the nearest 0.1cm using a height meter. Participants will be asked to remove shoes, stand erect, looking straight in a horizontal plane with feet together and knees straight. Each measurement will be taken twice on each respondent and the average taken.

Mid upper arm circumference (MUAC) of the participants will also be taken. A flexible non-stretch tape will be used to take the measurement, the participants will be asked to stand erect and sideways to the measurer with the head in Frankfurt plane, arms relaxed and legs apart. The measurement will be taken at the midpoint of the left upper arm.

Participant will complete a 7 days food record. The type of food eaten, and the volume of cooked food consumed by the participants will be recorded using standard tools (utensils).

Blood and stool samples will be collected to determine the level of hemoglobin; this will be done by a trained laboratory technician.

**Risks**

No risk will be imposed to the participants

**Compensation mechanism if any**

There will be no compensation since there will be no risk imposed to participants

**Voluntarism**

Participation in the study is voluntary and if the participant refuses to comply, it will not result in any penalties. A participant has a right to withdraw from the study if she wishes at any time.
Type of specimens and amount to be obtained

Blood samples of 5mls will be taken for analysis of hemoglobin, stool samples for analysis of worms.

Information on the researchers.

Incase you wish to contact the researcher on any issues related to the study, use the address below

Researcher : Judith Waswa

University of Nairobi, School of Agriculture and veterinary sciences
Department of Food Science, Nutrition and Technology
Cell phone: 0733533844/ 0719758589

Information on the Ethical Research Committee

Incase of any further information regarding the study contact the University of Nairobi Ethical Research Committee using the following address:

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P.o Box 19676 code 00202
Email uonknh_erc@uonbi.ac.ke
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Confidentiality will be assured and privacy will at all times be protected for the information given by the participant and used only for the purpose of the study

Possible storage of specimen for further analysis with the permission form the KNH/UON/ERC
Specimens may be stored in glass or plastic vials as long as the vials are tightly sealed to prevent desiccation of the sample during transportation of samples to the laboratories. Samples may also be refrigerated incase the analysis is delayed.

CONSENT (for participants >18 years): Upon reading, all aspects pertaining to the study and adequate understanding of the study, I hereby declare my voluntary informed consent to participate in the study.

Signature-------------------------------------                    Date-------------------------
APPENDIX II

CONSENT FORM FOR BASELINE SURVEY (parents)

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Participant will complete a 7 days food record. The type of food eaten, and the volume of cooked food consumed by the participants will be recorded using standard tools (utensils).

Blood and stool samples will be collected to determine the level of hemoglobin and stool samples for analysis of worms; this will be done by a trained laboratory technician.

Risks

No risk will be imposed to the participants

Compensation mechanism if any

There will be no compensation since there will be no risk imposed to participants

Voluntarism

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Reseacher : Judith Waswa

    University of Nairobi

    School of Agriculture and veterinary sciences

    Department of Food Science, Nutrition and Technology

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**Consent (for minors < 18)**

Upon reading, all aspects pertaining to the study and adequate understanding of the study, I hereby give my voluntary informed consent for my daughter to participate in the study.

Name……………………………………………………………………………………………………………………………………………………………………

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Signature--------------------------------------                    Date------------------------------------
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Those who will volunteer to participate in the study will be stratified according to class and randomized to get the desire sample of 52 participants for the intervention sample. A table of
random numbers will be used. The 52 participants will be asked to consent by signing the consent form. They will further be stratified according to class and randomized to the treatment groups A and B. A statistician will determine the allocation sequence, random number tables will be used, and the randomization will be implemented by the statistician. Permutated blocks will be created for each class. Each block will have equal number of treatments (A) and controls (B). Blocks of four (4) will be created; a total number of six (6) blocks per group will be created. The blocks will be chosen at random using random number tables and treatments allocation done according to that block, then another block is chosen at random and treatments allocated according to that block, this will continue until the required sample size is reached.

Benefits

All participants in will be given de-worming drugs and malaria prevention drugs. Participants in the treatment group will be given a snack to replace soil.

Risks

No risk will be imposed to the participants

Compensation mechanism if any

There will be no compensation since there will be no risk imposed to participants

Study procedures

During the intervention phase there will be two groups: an intervention group, a control group. Immediately before the intervention the participants will fill a questionnaire, blood and stool samples will be collected, this will be done by a trained laboratory technician. Soil samples eaten by the participants will also be collected and analyzed to determine the amount of iron and presence of helminthes.
Albendazole (400 mg) single dose and fansider will be given to both groups as treatment to helminthes infestation and malaria prophylaxis respectively at the beginning of the study. The treatment group will be given the snack but the control group will not be given.

The mount of snack to be given per day will depend on the average amount of soil eaten per day which will be determined at baseline. The researcher will give the snack to the participants daily and build confidence in them to ensure compliance. An intervention schedule (register) will be used, the schedule will comprise of the name, class, and date/day of snack collection. The register will help in monitoring progress of the intervention. The participants will be advised to treat the snack as a treatment and not to share out to friends in the to ensure compliance and avoid contamination. Participants will be advised to eat the snack any time they feel like eating soil. Each time the participants go to collect the snack, the researcher will discuss with each one of them about the intervention snack and its importance to ensure compliance. The participants will be encouraged to report any side effect caused by eating the snack. The behavior of eating soil among the participants of the treatment group will also be monitored.

Participants in the control group will be advised not to share the snack with those in the treatment group. They will be advised to take some little soil whenever they have the urge. They will meet the researcher at least once in a week, during the meeting they will discuss on the frequency and amount of soil they eat and any side effects.

Data on geophagy and hematological status will be collected eight weeks after enrolment. All girls will be interviewed to obtain information about geophagy.
Voluntarism

Participation in the study is voluntary and if the participant refuses to comply, it will not result in any penalties. A participant has a right to withdraw from the study if she wishes at any time.

Type of specimens and amount to be obtained

Blood samples of 5mls will be taken at the start and end of the intervention. Stool samples will also be taken. Participants will also provide the type of soil eaten (100g)

Follow up schedules if applicable/expected time in the study

Participants in the intervention study will be followed up for 8 weeks as they feed on the snack

Follow up schedule

Date of enrolment ..............................................

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<tr>
<td>Week 6</td>
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<tr>
<td>Week 7</td>
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<tr>
<td>Week 8</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Information on the researchers.

In case you wish to contact the researcher on any issues related to the study, use the address below

Researcher: Judith Waswa

University of Nairobi

School of Agriculture and veterinary sciences

Department of Food Science, Nutrition and Technology

Cell phone: 0733533844/ 0719758589
Information on the Ethical Research Committee

In case of any further information regarding the study contact the University of Nairobi Ethical Research Committee using the following address:

University of Nairobi
College of health Sciences
P.o Box 19676 code 00202
Email uonknh_erc@uonbi.ac.ke
Tel. (020) 2726300 Ext. 44355

Confidentiality

Confidentiality will be assured and privacy will at all times be protected for the information given by the participant and used only for the purpose of the study

Possible storage of specimen for further analysis with the permission form the KNH/UON/ERC

Specimens may be stored in glass or plastic vials as long as the vials are tightly sealed to prevent desiccation of the sample during transportation of samples to the laboratories. Samples may also be refrigerated incase the analysis is delayed.

Consent (for minors < 18)

Upon reading, all aspects pertaining to the study and adequate understanding of the study, I hereby give my voluntary informed consent for my daughter to participate in the study.

Signature--------------------------------------                    Date------------------------
APPENDIX V

ASSENT FORM FOR PARTICIPANTS UNDER 18 YEARS

STUDY TITLE: DEVELOPMENT AND UTILIZATION OF A FOOD REPLACER
FOR GEOPHAGIC ADOLESCENT GIRLS

TICK all you agree with:

Have you read (or had read to you) about this project? Yes/No

Has somebody else explained this project to you? Yes/No

Do you understand what this project is about? Yes/No

Have you asked all the questions you want? Yes/No

Have you had your questions answered in a way you understand? Yes/No

Do you understand it’s OK to stop taking part at any time? Yes/No

Are you happy to take part? Yes/No

If any answers are ‘no’ or you don’t want to take part, don’t sign your name.

If you do want to take part, you can write your name below

Your name ___________________________

Date ___________________________

Researcher:

Name ___________________________

Sign ___________________________

Date ___________________________

Thank you for your help.
APPENDIX VI

SENSORY EVALUATION FORM

Taste the product given and use the scale below to indicate how much you like it.

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall /preference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7-Like Extremely  6-Like Moderately  5-Like Slightly  4- undecided
3-Dislike Slightly  2-Dislike Moderately  1-Dislike Extremely

Taste Panel Procedure and Descriptive Comments Form

The following guidelines should be followed when rating a food product on the Taste Panel:

1. Emphasis is on the quality of the food product rather than on personal preferences such as likes and dislikes.
2. If you absolutely dislike the food product because of personal preferences, do not rate it.
3. If a product is rated below a 6 for any category, then note the reason in the space provided.
4. The overall rating is your overall general impression of the product, which is not necessarily an average of the other categories, but should be consistent with them.
5. Do not talk with other panelists during evaluations.
6. Refrain from smoking, eating, or drinking for 60 minutes prior to panels.
7. If necessary, use water or crackers between samples to clear the palate.
8. If you have a question regarding the Taste Panel, ask the person conducting the panel.
Descriptive Comments

Here is a list of descriptive terms that can be used to describe an attribute of a food and be an aid for food development. You may use the list below to describe attributes of a food sample.

A score of 6.0 or below should have some descriptive comment that will explain a low score.

<table>
<thead>
<tr>
<th>Taste/Odour</th>
<th>Texture</th>
<th>Color/appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitter Crisp</td>
<td>Dull</td>
<td></td>
</tr>
<tr>
<td>Sweet</td>
<td>Soft</td>
<td>Lustrous</td>
</tr>
<tr>
<td>Sour</td>
<td>Hard</td>
<td>Sparkling</td>
</tr>
<tr>
<td>Salty</td>
<td>Tough</td>
<td>Bright</td>
</tr>
<tr>
<td>Oxidized</td>
<td>Firm</td>
<td>Light</td>
</tr>
<tr>
<td>Rancid</td>
<td>Chewy</td>
<td>Dark</td>
</tr>
<tr>
<td>Stale</td>
<td>Rainy</td>
<td>Greasy</td>
</tr>
<tr>
<td>Tasteless</td>
<td>Gummy</td>
<td>Glossy</td>
</tr>
<tr>
<td>Metallic</td>
<td>Mushy</td>
<td>Old</td>
</tr>
<tr>
<td>Flat</td>
<td>Pastry</td>
<td>Pale</td>
</tr>
<tr>
<td>Musty</td>
<td>Rubbery</td>
<td></td>
</tr>
<tr>
<td>Yeasty</td>
<td>Greasy</td>
<td></td>
</tr>
<tr>
<td>Floral</td>
<td>Juicy</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX VII

QUESTIONNAIRES

QUESTIONNAIRE (Baseline study)
Questionnaire no…………………………………………………………

Part I At first contact with participants
Tick the correct response in the spaces ( ) provided
(A) Socio-demographic characteristics

1. a) class
   Form 1 ( ) Form 2 ( ) Form 3 ( ) Form 4 ( )

2. Age
   1. 13 -15 ( ) 2. 16 – 20 ( ) 3. Above 20 ( )

3. Does you mother or any relative you stay with eat soil?
   1. yes ( ) 2. No ( )

4. Occupation of parent
   1. Not employed ( ) 2. Small business ( )
   3. Farmer ( ) 4. Professional job ( )

5. How many people do you share meals with at home?
   1. ≤ 5 people ( ) 2. > 5 people ( )

6. What is your home setting?
   1. Rural ( ) 2. Urban ( )

7a). For how many days do your periods last?
   1. Less than 3 days ( ) 2. 3-5 days ( ) 3. 6-10 days ( ) 4. More than 10 days ( )

(b). How many sanitary pads do you use in a day?
   1. 2-3 ( ) 2. 4-6 ( ) 3. More than 6 ( )

8a. Do you eat soil? 1. Yes 2. No ( )
If your answer above in 7a above is yes answer section b-g

b) Which type of soil do you eat?
   1. Buy from market ( ) 3. Get from anthill ( )

   c) Give the approximate amount of soil you eat in a day
      1. 1-2 tablespoon(10g-20g) 2. 3-4 tablespoons (30g-40g) ( )
      3. 4-5 table spoon (40g-50g) ( ) 4. More than 5 table spoons ( )

d) When did you start eating soil? 1. Before I started having my periods ( )
   2. Immediately after I started my periods ( )
3. Any other time (specify)

e) How many times in a day do you eat soil
   1 once ( ) 2. Twice ( ) 3. more than twice ( )

(f) Do you eat soil while at home?
   1. Yes ( ) 2. No ( )

g). Give reasons why you eat soil.
   1. I feel the urge of eating
      1. yes ( ) 2. No ( )

   2. I eat to avoid nausea and vomiting
      1. yes ( ) 2. No ( )

   3. I eat when am hungry
      1. yes ( ) 2. No ( )

   4. Any other reason ( specify)……………………………………

h). Any abdominal disorder or distress after eating soil
   1. Yes ( ) 2. No ( )

(b) Nutritional factors
12 Weight (kg) Observation 1……………………………
   Observation 2……………………………

   1. <50kg ( )
   2. 50 – 55 kg ( )
   3. 56 – 60 ( )
   4. ≥ 61 ( )

13. Height (cm) Observation 1……………………………
   Observation 2……………………………

14. MUAC (cm)……………………………

   1. < 22 ( )
   2. 22 – 23.9 ( )
   3. ≥ 24 ( )

15. Hemoglobin ……..value …………..

   1. Severe (< 12g/dl) ( )
   2. Marginal – normal (> 12g/dl) ( )

QUESTIONNAIRE (Before Intervention)
Questionnaire no………………………………………………

Part I  At first contact with participants
Tick the correct response in the spaces ( ) provided

(B) General characteristics
1. Class
   1. Form 1 ( )  2. Form 2 ( )  3. Form 3 ( )  4. Form 4 ( )

2. Age
   1. 13 -15 ( )  2. 16 – 20 ( )  3. Above 20 ( )

3. Does your mother or any relative you stay with eat soil?
   1. yes ( )  2. No ( )

4. Occupation of mother/guardian
   1. Not employed ( )  2. Small business ( )  3. Farmer ( )  4. Professional job ( )

5. When did you start eating soil?
   1. Before I started having my periods ( )
   2. Immediately after I started my periods ( )
   3. Any other time (specify)…………………………

6. Which type of soil do you eat?
   1. Buy from market ( )  2. Remove from house ( )  3. Get from ant hill

7. Give the approximate amount of soil you eat in a day
   1. 1-2 tablespoon(10g-20g) ( )
   2. 3-4 table spoons (30g-40g) ( )
   3. 4-5 tablespoon (40g-50g) ( )
   4. More than 5 table spoons ( )

8. How many times in a day do you eat soil
   1. once ( )  2. Twice ( )  3. more than twice ( )  4. other times (specify)……………………………………………………

   1. I feel the urge of eating  1. yes ( )  2. No ( )
   2. Because my friend/relative are eating  1. yes ( )  2. No ( )
   3. I eat when I am hungry  1. yes ( )  2. No ( )
   4. Any other reason (specify)……………………………………

10. Do you normally have any abdominal disorder or distress after eating soil.
    1. Yes ( )  2. No ( )

(B) Nutritional factors

11. Weight (kg) Observation 1…………………………
    Observation 2………………………………………………
    1. <50kg ( )
    2. 50 – 55 kg ( )
    3. 56 – 60 ( )
4. ≥ 61

12. **Height (cm)**…Observation 1……… Observation 2………

**MUAC (cm)**…Observation 1……… Observation 2………

1. < 22
2. 22 – 23.9
3. ≥ 24

13. **Hemoglobin** ………value …………………

   1. Severe (< 12g/dl)   ( )
   2. Marginal – normal ( >12g/dl) ( )

14. **Hematocrit ratio**……value …………………

   1. Severe(<37)   ( )
   2. Marginal – normal (>37)   ( )

15. **Mean Corpucular Volume MCV**……Value

   1. severe (>78)
   2. Marginal – normal (< 78)
QUESTIONNAIRE (After intervention)
Questionnaire no..........................

PART III - After 8 weeks

Tick the correct response in the spaces ( ) provided

Do you still feel like eating soil?
1. yes ( ) No ( )

Hemoglobin .................................
1. Severe ( < 12g/dl) ( )
2. Marginal – normal (>12g/dl) ( )

Hematocrit ratio ..........................
1. Severe (<37) ( )
2. Marginal – normal (>37) ( )
APPENDIX VIII

INTERVENTION SCHEDULE

Questionnaire no……………………..
Name …………………………………………

Date of enrolment …………………………………..
Anti helminthes treatment ( )…………………………

<table>
<thead>
<tr>
<th>Intervention schedule</th>
<th>Mon</th>
<th>Tues</th>
<th>Wed</th>
<th>Thur</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td></td>
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<td>Week 2</td>
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<td>Week 4</td>
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<td>Week 5</td>
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<td>Week 6</td>
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<td>Week 7</td>
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<tr>
<td>Week 8</td>
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</tbody>
</table>
APPENDIX X

7 DAYS RECORD

Please answer the following questions study No ………

24 HOUR RECORD

<table>
<thead>
<tr>
<th>Day</th>
<th>Details of food or drink</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monday</td>
<td></td>
<td></td>
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<tr>
<td>Tuesday</td>
<td></td>
<td></td>
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<tr>
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<tr>
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<td></td>
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<tr>
<td>Friday</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturday</td>
<td></td>
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</tbody>
</table>