The State of Food Security and Nutrition : Building Climate Resilience for Food Security and Nutrition in the South West Region, Cameroon

Bernard Tiencheu, Mireille Sylviane Dongmo Nguepi, and
Achidi Aduni Ufuan (University of Buea, Cameroon)

Abstract

Purpose: Climate change poses a growing threat to the achievement of adequate nutrition; it is projected to negatively affect human wellbeing and nutrition. The aim of this paper is to compare empirical literature from FAO food composition table (FCT) (1966) with our actual nutrients experimental data, to better understand the pathways linking climate change and nutrition after a period of 55 years (1966-2022) and to provide mitigating/resilience studies for this global syndemic between climate change and nutrition.

Design: A conceptual search on climate change related conditions that may affect agricultural/food/water chain and quality in South West region Cameroon was done. Secondly, staple foods were purchased to establish and compare their nutrient composition with the FCT. In a bid to mitigate and be resilient to the impact of climate on nutrients deficit, two pilot food studies (nutrients enhancement studies) were conducted in partnership with local small scale producers.

Findings: Results of conceptual framework revealed that, heat-waves, droughts, heavy precipitations and floods, due to climate and global environmental change events could be the key drivers behind the rise in malnutrition because they impact on water, crop yields, vegetation and food security. Furthermore, comparing 1966 food composition table with the analysed chosen staple foods showed a significant decrease of the micronutrient content with years; indicating that food systems are vulnerable to the increased variability in the weather and ecosystem as a result of climate change. Pilot studies with our partners revealed that formulated Fortified foods studied improved the micronutrients adequacy.

Keywords: Climate change, Nutrition, Food composition table, Human health, Nutrient, Staple foods, Food security

Introduction

Climate change and malnutrition in all its forms constitute two of the greatest threats to planetary and human health. The costs of unmitigated climate change, which will disproportionately affect low-income countries (Swinburn et al., 2019). The future of our health and that of our planet depend on our ability to massively reduce our contribution to climate change. No single solution will suffice. Nonetheless, changes in the food choice, and agricultural system can help mitigate climate change impacts on nutrition. The pandemics of malnutrition and climate change constitute a syndemic (Kahn et al., 2019): they interact in time and place, have synergistic adverse effects on each other, and importantly, share common underlying features.

As the climate changes, ensuring long-term access to sufficient and nutritious food for all becomes an even greater challenge faced by humanity. The effects of climate change on under-nutrition would be devastating, and would undermine current efforts to reduce hunger and ensure good nutrition. Despite the obvious critical situation and strong interconnection, food and nutrition security is still markedly absent in climate change negotiations. While strengthening further efforts on mitigation, it is time for climate negotiators, governments and donors to focus their attention on the consequences of climate change on under-nutrition/over-nutrition, and commit urgently to help the most vulnerable to adapt to an increasingly unpredictable climate and world. If not, irreversible consequences can be expected.

Adverse effects of climate change are a reality: the number of climate-related disasters (drought, floods, cyclones, etc.) in the previous decade has more than doubled relative to the nineties (WMO, 2021). It is proved that they are main drivers affecting food insecurity both in the aftermath of a disaster and in the long-term (Shimada, 2022). Climate-related events, disturbances in seasonal patterns, and gradual climate and temperature changes increase the overall risk of hunger. This is particularly alarming as there are still 842 million people suffering from hunger and more than 180 million children affected by under-nutrition (FAO, 2013). The situation is very likely to get worse considering the various predicted impacts of climate change. With a +2°C global average temperature increase, the most optimistic projected warming scenario is that the rate of undernourishment in the sub-Saharan African population will increase by 25% - 90% by 2050, relative to today (Lloyd et al., 2011; FAO, 2017). Climate change will affect the world's poorest households, whom have insignificantly contributed to greenhouse gas emissions. Furthermore, the most affected are those who have the least capacity to adapt to climate change related impacts.

The South West Region of Cameroon is blessed with a variety of natural resources such as; forests, water bodies (waterfalls, rivers, lakes, and ocean), mountains and abundant wildlife species. Moreover, climate in this region favors human habitation with temperature ranging from 16 to 26^{o} C and an annual rainfall of 1432.2 mm, thus promoting agricultural practices. The most visible effect of urban expansion in South West Region of Cameroon is discernible in the urban and peri-urban areas, especially in Buea, Tiko and Limbe which have witnessed rapid population growth, ecosystem and environmental destruction and climate change (Nde-Fon and Assob, 2013).

Cameroon has witnessed a rapid and uncontrolled urban growth, especially at the peri-urban fringes (Akoko et al., 2019). With a constant rise and change of climate, urban dwellers are obliged to record a high household dependency ratio. In response, households have developed resilience techniques to cope with the changing climate and changing food. To survive within the urban and semi-urban areas of the region, the situation is more challenging among the poor whose purchasing power has consistently been eroded by falling real wages, inflation and the rising cost of living despite attempts by the government to increase minimum wages (Bronhilda, 2012). The objective of this paper is to investigate on nutrition from a climate change perspective and to build resilience for food insecurity in the South West Region, Cameroon.

Materials and Methods

Study Design

This work is divided into three sections (Figure 1): First, a conceptual work linking environmental, anthropometrical and natural climate change key drivers in the South West Region that may impact nutrition. Secondly, comparison of empirical literature from food composition table (1953) published in 1966 by the FAO to explore the nutrients content of common staple foods with our actual experimental data (year 2022). Thirdly, in order to mitigate food insecurity, we proposed two pilot food studies conducted in partnership with local small scale producers as resilience strategy.

Study Area

This research takes into account three municipalities in the Fako Division of the South West Region of Cameroon, namely; Limbe, Buea and Tiko municipalities (Figure 2). Limbe is a seaside city located along latitude 4° 00’ 60.00’’ N and longitude 9° 12’ 60.00’’ E of the Greenwich meridian. The area called Limbe is actually comprised of the main city of Limbe, surrounded by smaller villages such as Batoke, Ngeme, Debunscha, Idenau, Mokundange, Bonadikombo, Wututu and Bonjongo. The population of Limbe is 72106. The majority of people here are traders, with those in the neighboring villages and creeks mostly surviving on fishing and agricultural activities (Geonames, 2022).

Buea is a small town located at the eastern slope of mount Cameroon, and lies along latitude 4° 09’ 9.72’’ N and longitude 9° 14’ 27.60’’ E of the Greenwich meridian. As of the 2013 census, it had a population of about 300,000 (NIS, 2015). It is made of localities like Molyko, Bunduma, Tole, Soppo, Bova, Mile 16, Mile 14, Gbitingi and Bokwaongo. Majority of the adult population are business people with a considerable student population since Buea is hosting one of the state Universities. Buea has a typical mountain equatorial climate with a rainy season and a dry season having an annual rainfall between 3000-5000 mm.

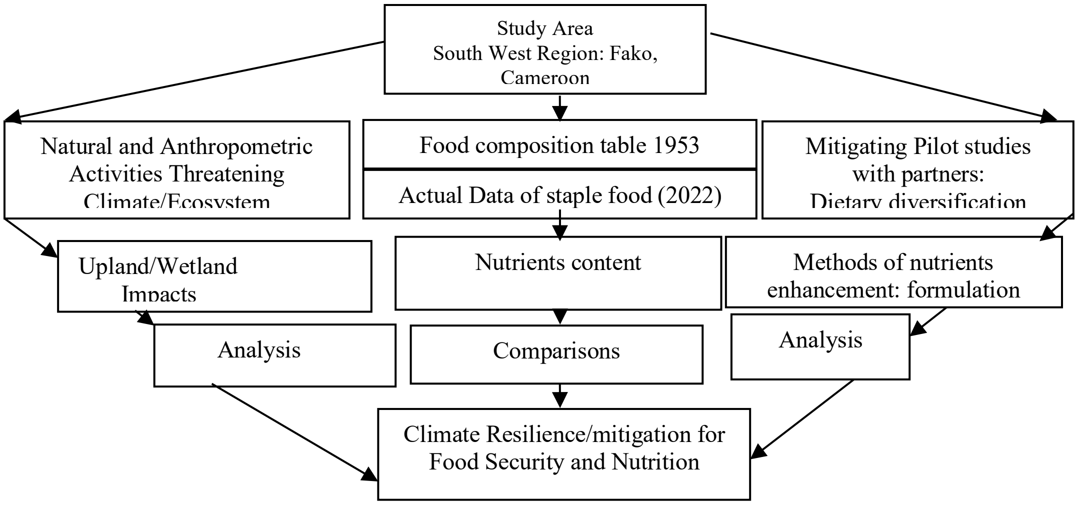

Figure 1: Overall Work Design Flow Chart

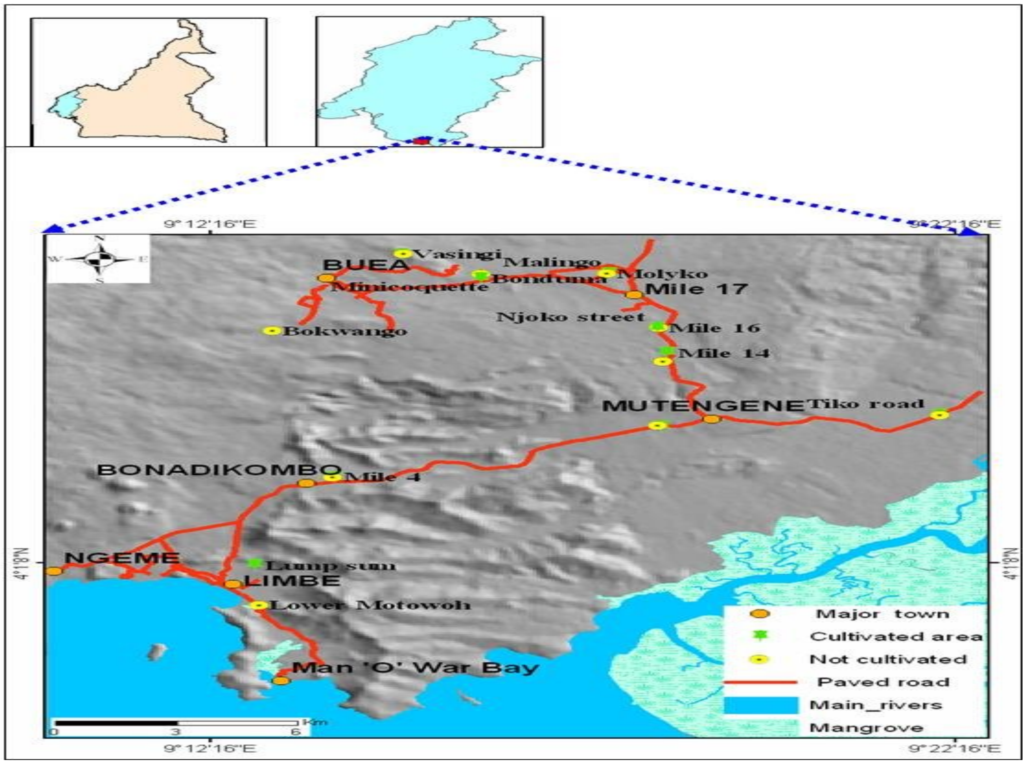

Figure 2: Map of the Study Areas

Tiko is a town located along parts of the Atlantic Ocean, along latitude 4° 04' 30.00'' N and longitude 9° 21' 36.00'' E, and is made of localities like Likomba, Tiko, Mutengene, Ombe, Mudeka, Mondoni, Misselele and Matte. It is host to the CDC and has a population of about 78,885 as at 2015 (NIS, 2015). The majority of people in this area are small scale farmers, and CDC workers.

Conceptual Framework on Natural and Anthropometric Activities Threatening Climate and Ecosystem of the Region

In order to conceptualize pathways and links that may alter nutrition at upland and wetland level of the study area (climate, environment, ecosystem and anthropometric activities on dry and wetland), we did a combination of scoping internet searches, snowballing, and citation tracking (Neba et al., 2021; Forkam et al., 2020; Akoko et al., 2019; Bate et al., 2019; Balgah et al., 2017; Azinwi et al., 2012; Molua, 2010; Molua, 2009; Feka and Manxano, 2008) to come up with frameworks. We merged nine frameworks which we found to accurately represent the climate and agricultural practices and nutrition science to create our own “meta-framework” (Figure 1). The choice of these frameworks was based on detailed comparison of identified frameworks and discussion among the article authors, which included representation of experts on climate change, public health nutrition, human activities, and natural seasonal change; the information derived was recapitulated into factors affecting highland and lowland of the studied area.

Nutritional Analysis

Empirical Food Composition Table

To compare empirical literature from food composition table (1953) published in 1966 by FAO, to explore the micronutrient content of common staple foods with our actual experimental data, to better understand the pathways linking climate change and nutrition after a period of 55 years (1966-2021) and to provide recommendations to mitigate the global syndemic between climate change and nutrition, a document (food Composition table) was downloaded from https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_5/b_fdi_14-15/20430.pdf and https://www.fao.org/infoods /infoods/tables-and-databases/cameroon-archives/en/ with the following reference https://www.fao.org/infoods/infoods/tables-and-databases/cameroon-archives/en/.

https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers13-01/09986.pdf, and was used for comparison with our actual 2021-2022 food composition (empirical work).

Determination of our Actual Staple Food Composition

Sample Collection

The major foods which are cultivated in these municipalities include yellow corn maize, beans, cassava, cocoyams, plantains, yams, rice, Irish potatoes, tomatoes and sweet potatoes. The raw ingredients for the formulation of the complementary food and juices; were rice, corn, soybeans, sweet potatoes, irish potatoes, eggs, sugar, soybeans oil, pawpaw, watermelon, pineapple, oranges and sugar. They were bought from the local farmers of the region. The samples were taken in a polythene bag to the University of Buea Life Science Laboratory for formulation and nutritional analyses.

Proximate Analysis and Minerals Content

Standard procedures of AOAC were used to determine the moisture content, crude fat, crude protein (N x 6.25), crude fibers and ash. The total carbohydrate was obtained by difference. Energy value was calculated using the Atwater's conversion factors. Minerals were determined by Atomic Absorption Spectrophotometer, Hitachi Model 180-80, and Ion Chromatographic Analyzer ICA model IC 100 (AOAC, 2005).

Climate Resilience/Mitigating Pilot Studies with Partners: Methods of Nutrient Enhancement: Dietary Diversification, Formulation, Fermentation Fortification

In order to solve any possible micronutrient deficiencies that may have been impacted by climate and ecosystem modification on the nutrient quality of foods, two pilot food studies were conducted in partnership with local small scale producers (Hest, Jourlaitcam, Saphi Beverages Scoop and Islamic Development Bank). The studies focused on formulation of natural juice by blending several ingredients while the other focused on formulation and fortification of complementary food using germination/fermentation technology. This was done on staple foods in a bid to improve on the human micronutrients requirement.

First Pilot Study: Juice Formulation

Sample Collection

Healthy mature, ripe lemon, honey and orange fruits and fresh ginger were bought from local farmers at the Buea Central Market. The samples were taken to the University of Buea Life Science Laboratory in a polythene bag for juice formulation and nutritional analyses.

Sample Preparation

The fruits (orange and lemon) were washed, weighed, peeled and reweighed. The lemon and orange juices were extracted separately using an electronic juice extractor (Citrus juicer, CJ625). Both juices were filtered and then bottled and kept for formulation and pasteurisation.

The ginger on the other hand, was washed, weighed, chopped into smaller sizes and blended with 600mL of water using a Moulinex (PHILIPS). The ginger due to its rich fibre content had much chaff hence, was squeezed and filtered with a 0.2μm sieve, before the tea sieve was used. This was also ready for formulation and pasteurisation.

Juice Formulation

Five (5) juice formulas (Blending recipes termed: F1, F2, F3, F4 and F5) (Table 1) were made ranging from 5% to 10% orange or lemon fruit base and were labelled from F1 to F5. This was done using a formulation table (Table 1). The juices were pasteurized at 90 ºC for 10 minutes. They were allowed to cool for 45 minutes and filled into sterile labelled bottles and were analysed nutritionally as described previously in section 2.4.2.

Table 1: Formulation Table

Juice Code	Orange	Lemon	Ginger	Honey	Table sugar	Vanilla sugar	Water	Total (mL)
F1	5	0	5	10	5	0	75	100
F2	10	0	5	10	0	5	70	100
F3	0	10	5	10	5	0	70	100
F4	0	5	5	10	5	0	75	100
F5	0	10	5	10	0	5	70	100

F1, F2, F3, F4 and F5= different formulated juices

Second Pilot Study: Complementary Food Formulation

Sample Preparation and Processing

Preparation of Flours

Malted corn flour was prepared by soaking overnight, kept in a cool dry place, and covered with plastic bags for germination. The fermented and malted corn flour was obtained using the optimal processing conditions as defined by Kameni et al. (2008)

Rice flour: This was done using the method described by An-I (2004).

Sweet potato flour: This was produced using the method proposed by Maninder and Kawaljit (2016).

Irish potato flour: This was produced using the method described by Maninder and Kawaljit (2016).

Soy protein flour: It was prepared following processing unit described by Wang et al. (2004).

Egg white flour: 90 fresh eggs were cracked open, and the yolks removed. The whites were dried at 50°C for 24 hours, ground using a dry electric blender, and sieved. The resulting flour was stored in zip-lock bags, inside an air-tight container at room temperature (Nahariah et al., 2018)

Extraction of Fruit Juices for Micronutrient Fortification of Foods

Fifteen medium sized oranges, 2 large pineapples, 2 large pawpaw fruits and one large watermelon were washed in running tap water and peeled. The peeled fruits were juiced individually using an electric juicer machine, sieved using a 0.1mm sieve, and stored in separate sterile containers at 4°C till when it was ready to be used as natural fortificants to enrich the formulae.

Blending, Formulation and Fortification

Table 2 is a summary of how the flours and juices were mixed in ten different proportions to give ten different food blends. Blend A, for example, consisted of 58g of malted corn flour, 10g of egg-white flour, 10g of soybeans flour, 8g of sugar, 5ml of soybeans oil, 50ml of watermelon juice, 10ml of orange juice, 40ml of pawpaw juice, 5ml of milk flavour, 5ml of coconut flavour and 12g of baking powder. After mixing of flours, juices and flavours, the mixtures were homogenized using an electric blender, placed on sterile trays and dried at 50°C for 24 hours using a hot-air oven. The resulting dry matter were ground using a dry blender, sieved and the fine flours (instant baby ready to eat foods) stored in sterile zip-lock bags at room temperature.

Table 2. Formulation of Ten Different Complementary Food Blends

Food samples/ Blends	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Corn Flour (g)	58	0	0	0	29	29	29	0	0	0
Rice Flour (g)	0	58	0	0	29	0	0	29	29	0
SP Flour (g)	0	0	58	0	0	29	0	29	0	29
IP Flour (g)	0	0	0	58	0	0	29	0	29	29
Egg White Flour (g)	10	7	8	6	10	8	6	5	3	5
Soy Protein Flour (g)	10	7	8	6	10	8	6	5	3	5
Sugar (g)	8	10	0	7	10	5	7	5	7	5
Soybeans oil (ml)	5	5	5	5	5	5	5	5	5	5
Watermelon juice (ml)	50	50	50	50	50	50	50	50	50	50
Pineapple juice (ml)	0	10	0	10	0	0	0	10	0	0
Orange juice (ml)	10	0	10	0	10	0	0	0	0	0
Pawpaw juice (ml)	40	40	40	40	40	50	50	40	50	50
Milk flavour (ml)	5	5	5	5	5	5	5	5	5	5
Coconut flavour (ml)	5	5	5	5	5	5	5	5	5	5
Baking soda (g)	12	12	12	12	12	12	12	12	12	12

SP: Sweet potato; IP : Irish potato

Statistical Analysis

Raw data were computed using Microsoft EXCEL 2007. All data were presented as mean ± SD and was analysed using one-way analyses of variance (ANOVA) using Graphpad software to test the level of significance at 5 % probability ($p<0.05$). Bonferroni Test was used to separate/compare the means where significant differences existed.

Results and Discussion

Conceptual Framework: Natural and Anthropometric Activities Threatening Climate/Ecosystem of the Region

The first section of the conceptual framework (Table 3) lays that heat waves, season short term trends, variation in precipitation or temperature, and meteorological events such as heat waves, droughts, and floods (Erudef, 2021) due to climate and global environmental change events are the key drivers behind the rise in hunger because they impact on water, food and nutrition security, particularly in developing countries. These were observed through many years of weather/meteorological variability. Consequently they alter relationships among crops, pests, weeds, pathogens; and exacerbate several trends including increasing water scarcity, decline in fishery /sea food and ocean productivity as well as an induced decrease crop productivity, land degradation, high market prices, and negative impacts on livelihoods, and increased malnutrition (Erudef, 2021). Climate change will impact malnutrition by affecting patterns in weather, including trends in precipitation and temperature, as well as the frequency and magnitude of extreme weather events. It is difficult to study climate associations (Molua, 2009). Erudef (2021) reported that, over the past 2 decades, this region has been exposed to climate change as a result of Greenhouse Gas (GHG) emission.

Table 3. Summary of the Conceptual Framework Showing Climate Change Conditions that Pose a Growing Threat to Nutrition in the Study Area

South West Location	Climatic and ecosystem Impact	References
Upland (Buea Highland)	- **Wild and bush fire (destruction of vegetation);** Huge smoke : air pollution (particles, sulfur dioxide, ozone, Carbon monoxide) - Disappearance of bush meats and edible insects causing pressure on cow meat price. - Destruction of sol, erosion, destruction or activation of soil microorganisms (azobacter). Soil leaching, leading to excessive utilization of fertilizer, insecticides and chemicals that facilitate plant growth and affect original food taste. - Change of agricultural practices to adapt to new soil. - Deforestation. - Urbanization: destruction of cultivable surface - Violent winds, high temperatures, irregular rainfall, floods and landslides which endanger communities' ecosystems and the services they provide. - Poor agricultural techniques, poor waste disposal, plastic pollution - Increase in epidemics, food and water scarcity, changes in	Neba et al., 2021; Akoko et al., 2019; Forkam et al.,2020; Feka and Manxano, 2008; Molua, 2009; Molua, 2010; Azinwi et al., 2012; Bate et al., 2019; Balgah et al., 2017

	temperature and precipitation, leading to droughts and floods.	Nde-Fon and Assob, 2013 Aaron et al., 2014 Neba et al, 2021 Erudef, 2021
Wetland (Tiko, Limbe)	- Seasonal inconstancy (modification of rain flow rate and rain precipitations. - Flow of mangrove, destruction of mangrove for firewood that affect phytoplankton's, development of toxic wild algae that reduce dissolvable oxygen, fish scarcity, animal migration. - Increase of sea level, Water acidification, heavy metal accumulation - Change of vector, pest and insects life cycle, - Water borne disease, Contamination of ground water by run-off water and toilet. - Human anthropometric activities: laundry contaminate drinking and domestic water sources (well, river, bore water, food contamination, food intoxication,	

Consequently, the population are facing abnormal recurrence of extreme weather phenomena such as violent winds, high temperatures, irregular rainfall, floods and landslides which endanger communities' ecosystems and the services they provide. These environmental hazards are as a result of uncontrolled human activities which are not in conformity to environmental principles and disciplines, hence causing global warming. These activities include, but not limited to deforestation, poor agricultural techniques, poor waste disposal, plastic pollution and the absence of infrastructural town planning. There is much scientific evidence that climate change is responsible for increase in epidemics, food and water scarcity, changes in temperature and precipitation, leading to droughts and floods, poor agricultural yields and malnutrition (Nde-Fon and Assob, 2013). As climate change appears to be progressing too quickly for decisions to be delayed, we need to develop national and local climate change institutional frameworks to strengthen the coordination, networking and information flow at different levels of governments and local civil society to have better response to climate change eradication.

Comparison of Food Composition Table (1953) and Actual Data of Staple Food (2021-2022)

Table 4 presents the composition of some selected staple foods grown in the South West Region of Cameroon. According to this, different types of food are found in the region including cereals, tubers/roots, vegetables and fruits. The different micronutrients vary according to the type of food concerned with the highest amount of carbohydrates and proteins found in cereals in general and, particularly in fresh corn and the smallest value in fruits. The highest value of ash (total minerals) was found in fruits. The highest amount of calcium was found in pineaple, whereas phosphorous and iron were found in corn and rice in highest amount. This table also presents the nutrient composition of some staple foods recently evaluated for their nutrient content. This study revealed that the amount of micronutrients initially present generally reduced, while macronutrient increased and the food became more starchy and bulky. These modifications of staple food nutrients can lead to malnutrition (micronutrient deficiency and over-nutrition). Diet is changing too, especially among urban groups, with increased consumption of ultra-processed food and beverages, beef and dairy products, whose production is associated with high GHG emission intensities (Gill et al., 2015). These changes between 1966 and 2022 may be due to the rising levels of carbon dioxide from human activities. Gill et al (2015) reported that CO_2 can make staple crops less nutritious; elevated CO_2 generates hidden hunger by reducing mineral contents in cereal crops.

Research led by Myers et al. (2014) found that when food crops like wheat, corn, rice and soy are exposed to CO_2 at levels predicted for 2050, the plants lose as much as 10 % of their zinc, 5 % of their iron, and 8 % of their protein content. Studies by Nelson et al. (2009) revealed that the number of malnourished will probably increase due to climate change, with the majority of these children living in sub-Sahara Africa. People eat different diets and therefore the starting points in making dietary changes to move towards healthy and sustainable diets vary between people (Reynolds et al., 2019).

Table 4. Nutrient Composition of Some Staple Foods Derived for FAO (1966) Food Composition Table

	Proteins(g)		**Carbohydrate (g)**		**Minerals (Ash (g))**		**Calcium (mg)**		**Phosphorus (mg)**		**Iron (mg)**	
Food	FC	AC	PC	AC	PC	AC	PC	AC	PC	AC	PC	AC
Fresh corn	9.8	9.0	76.4	77.4	1.1	0.8.	12	10	220	218	2.0	1.7
Dry corn	6.6	6.6	48.8	50.4	0.5	0.4	32	30	137	133	3.2	2.2
Banana	1.2	1.0	25.5	28.5	0.8	0.3	4	3	40	39	0.7	0.6
Plantain	1.1	1.0	27.6	26.9	0.8	0.4	11	12	3.5	1.4	0.5	0.3
Cassava	0.9	1	37.7	38.5	1	1.	25	20	30	29	1.2	1.0
Tomato	1.2	0.9	5.6	3.2	0.4	0.1	10	7	45	42	0.7	0.6
Cocoyam	2.8	1.8	33.4	38.4	1.2	1.0	8	7	35	30	0.9	1
Rice	7	4.7	79.1	53.1	0.6	0.6	5	5	90	80	1	0.6
Yam	3.2	5.2	22.1	20.5	0.8	0.7	24	21	27	26	0.2	0.1
Sweet potato	1.8	3.3	25.3	30.6	0.9	0.8	36	30	60	56	1.4	1.2
Irsih potato	2.1	2.1	21.4	27.8	1.4	1.4	12	9	40	35	0.9	0.9
Mango	0.6	0.4	14.3	17.0	0.3	0.2	20	15	15	17	0.6	0.6
Pineapple	0.6	0.5	15.1	18.2	0.3	0.4	56	51	15	16	0.9	0.8
Avocado	2	2.1	6	8.3	1	0.9	18	14	57	51	0.8	0.6
Orange	0.8	0.6	12.2	9.2	0.5	0.3	28	22	28	18	0.1	0.2

FC: food composition from food composition table FAO, 1966 ; PC : Actual composition 2021-2022

There has been relatively limited consideration, however, of potential climate impacts on malnutrition through mechanisms of changing nutrient content of foods (Figure 3). Macronutrients and micronutrients are part of a healthy diet, and they ensure appropriate development and wellbeing and prevent diseases. Children aged between 6 months and 5 years in particular may suffer from micronutrient deficiencies (WHO, 2014). Vitamin A, calcium, and iron are the most common deficiencies and a concern for public health (WHO, 2021). Iron deficiencies in pregnant women increase the risk of maternal and child mortality, and low birth weight. Calcium deficiency affects the bone development of children, while vitamin A deficiency raises the probability of blindness and mortality due to infectious diseases during childhood (WHO, 2014). A 2018 study by Scheelbeek et al (2018) systematically investigated the effect of environmental change on vegetable and legume yields, in particular exploring projections in the potential future nutritional quality of vegetable and legume yields under environmental change. Generally, climate change affects the molecular function, the developmental process, the morphology and the physiological responses of plants (Myers et al., 2014). Elevated CO_2 promotes higher yields, but alters the equilibrium of the plant carbon metabolism and mineral composition (Soares et al., 2019: Nakandalange and Seneweera, 2018). For example, drought and high temperatures induce oxidative damage in legume plants according to the review of Soares et al. (2019), and this is more likely to have an effect on the macronutrients.

Some modelling and experimental studies conducted in laboratory have identified correlations between climate change or meteorological variation and a decrease in food quality in terms of diversity, nutrient density, and safety (Patz et al., 2005). Carbon dioxide (CO_2), for example, may have a negative effect on the nutritional content of several crops (Figure 3) (FAO, 2016; Porter et al., 2014). For example, concentrations of iron and zinc in wheat and rice are more likely to be reduced due to increased greenhouse gas emissions (Myers et al., 2014). Higher CO_2 associated with climate change is hypothesised to lead to micronutrient deficiencies (Smith et al., 2017; Müller et al., 2014; Myers et al., 2014). Among people worldwide that lack food, more have deficiencies in essential nutrients; 76% of the world’s population gets most of its daily nutrients from plants-yet climate change is already causing droughts and flooding that can destroy staple food crops. If extra CO_2 in the atmosphere makes those crops less nutritious (Figure 3), it will be even harder to feed the world’s growing population. While severe food insecurity and hunger are associated with lower obesity prevalence, mild to moderate food insecurity is paradoxically associated with higher obesity prevalence among vulnerable populations (Swinburn et al., 2019).

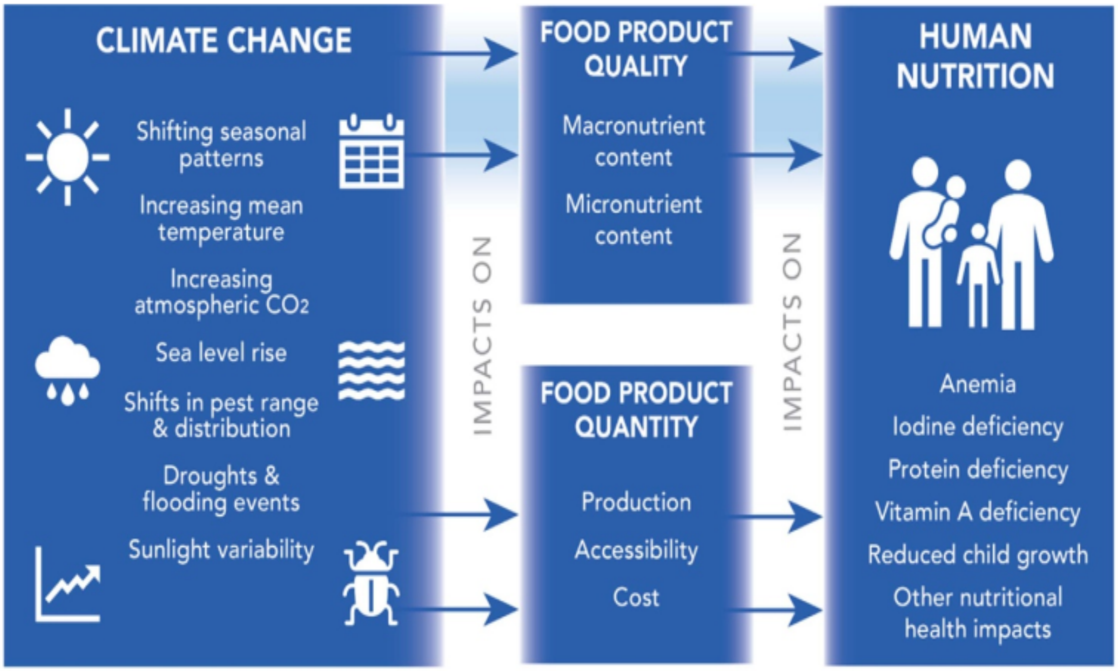

Figure 3: Climate change and nutrients (FAO, 2016 and NZFSSRC, 2019)

Mitigating Pilot Studies with Partners for the Nutrients Enhancement: Dietary Diversification, Formulation and Fortification

Proximate and Mineral Composition of Formulated Juices

Proximate Composition of Juice

The proximate composition of the best formulated juice is shown on Table 5. The protein content of the fruit juices was low. The general low protein content of fruit juice has also been reported for orange/pineapple juice blends and fresh beetroot juice (Ohwesiri et al., 2016; Emelike et al., 2015). According to Emelike et al. (2015) fruit juices are not good sources of protein. The carbohydrate content is higher than a reported range of 8.16 – 16.19% for orange/pineapple juice blends (Ohwesiri et al., 2016) and 7.3% for fresh beetroot juice (Emelike et al., 2015). The variations in these values could be associated with different fruits being analysed. The ash (mineral) content (0.51-1.13%) of the juices was similar to the range of 0.42% - 2.68% for orange/pineapple juice blends (Ohwesiri et al., 2016) and 0.64% – 1.32% for different brands orange juices (Ndife et al., 2015). Generally, the juices were rich in carbohydrate and moisture, but low in protein, fibre, fat and ash. The difference between the treatment means was significant ($P \leq 0.05$).

Table 5: Proximate Composition of Juice

Code	Moisture content (%)	Protein (g/100mL)	Carbohydrate (g/100mL)	Fiber (g/100mL)	Fat (g/100mL)	Ash (g/100mL)
F1	$96.84_{a} \pm 0.00$	$0.56_{b} \pm 0.00$	$21.83_{a} \pm 0.48$	$0.01_{a} \pm 0.00$	$0.11_{a} \pm 0.01$	$0.63_{a} \pm 0.00$
F2	$97.10_{a} \pm 0.36$	$0.01_{a} \pm 0.00$	$20.30_{a} \pm 0.99$	$0.02_{a} \pm 0.01$	$0.10_{a} \pm 0.00$	$0.51_{a} \pm 0.00$
F3	$96.84_{a} \pm 0.00$	$0.02_{a} \pm 0.00$	$22.99_{a} \pm 1.34$	$0.09_{a} \pm 0.00$	$0.10_{a} \pm 0.01$	$0.51_{a} \pm 0.01$
F4	$82.45_{b} \pm 1.86$	$0.01_{a} \pm 0.00$	$20.15_{a} \pm 2.04$	$0.02_{a} \pm 0.00$	$0.05_{b} \pm 0.01$	$1.13_{b} \pm 0.01$
F5	$79.31_{b} \pm 2.58$	$0.06_{a} \pm 0.00$	$16.39_{b} \pm 1.99$	$0.07_{a} \pm 0.00$	$0.10_{a} \pm 0.01$	$1.02_{b} \pm 0.00$

Results are expressed as mean ± standard deviation; a,b, Means with the same letter in the same column are not significantly different at p>0.05. F1, F2, F3, F4 and F5= different formulated juices

Mineral Analysis of Juice

Mineral content of the best formulated juice is presented on Table 6. The most abundant mineral was Potassium followed by Calcium while Zinc was the least. F1 was most abundant in Phosphorus and Magnesium, F2 in Iron, Zinc and Sodium, F3 in Potassium and F5 in Calcium; F4 was generally low in minerals. Minerals were significantly different ($P \leq 0.05$). This is in agreement with the results reported by Dosumu et al. (2009) and Ijah et al. (2015). The micro minerals, Iron (Fe) and Zinc (Zn) were present in trace amounts. Potassium is an essential mineral that works to maintain the body's water and acid balance. As an important electrolyte, it plays a role in transmitting nerve impulses to muscles, in muscle contraction and in the maintenance of normal blood pressure. While deficiency of potassium is rare, there is some concern that a high sodium-to-potassium intake ratio may be a risk factor for high blood pressure (Whitney and Rolfes, 1999). Generally, inadequate intake of micronutrients (minerals) has been associated with severe malnutrition, increased disease conditions and mental impairment (Dosumu et al., 2009).

Table 6: Mineral Composition of Juice

Mineral (mg/mL)	F1	F2	F3	F4	F5
P	$0.12_{c} \pm 0.02$	$0.08_{b} \pm 0.04$	$0.10_{b} \pm 0.01$	$0.01_{a} \pm 0.00$	$0.06_{b} \pm 0.00$
Fe	$0.06_{b} \pm 0.01$	$0.10_{b} \pm 0.03$	$0.07_{b} \pm 0.01$	$0.06_{b} \pm 0.02$	$0.06_{b} \pm 0.01$
Ca	$0.21_{c} \pm 0.05$	$0.19_{c} \pm 0.00$	$0.20_{c} \pm 0.03$	$0.19_{c} \pm 0.00$	$0.24_{c} \pm 0.00$
Mg	$0.07_{b} \pm 0.01$	$0.06_{b} \pm 0.03$	$0.06_{b} \pm 0.02$	$0.05_{b} \pm 0.00$	$0.04_{a} \pm 0.01$
Zn	$0.01_{a} \pm 0.00$	$0.02_{a} \pm 0.01$	$0.01_{a} \pm 0.00$	$0.01_{a} \pm 0.00$	$0.01_{a} \pm 0.00$
K	$0.23_{c} \pm 0.08$	$0.23_{c} \pm 0.08$	$0.29_{c} \pm 0.00$	$0.23_{c} \pm 0.08$	$0.23_{c} \pm 0.08$
Na	$0.08_{b} \pm 0.03$	$0.10_{b} \pm 0.00$	$0.08_{b} \pm 0.03$	$0.06_{b} \pm 0.00$	$0.06_{b} \pm 0.00$

Results are expressed as mean ± standard deviation; a,b,c, Means with the same letter in the same row are not significantly different at p>0.05. F1, F2, F3, F4 and F5= different formulated juices

This juice formulation section showed that blending or diversifying fruit can be a good mitigating strategy for the global challenges of ensuring sufficient safe and nutritious food for all. As our planet's population continues to grow, and as the impacts of climate change and environmental pollution become more visible to all, juice fortification and formulation solutions need to be promoted because it will be a good strategy to satisfy a daily human nutrient requirement in terms of recommended daily allowance (RDA).

Complementary Food Formulation

The nutritional composition of the formulated food is presented in table 7. For the ash contents, three out of five (Formula B, C and D) formulas had higher ash contents than the recommended value of 2.9. Formulas A and E had the least ash contents (2.65%), and these were the only two formulas whose ash contents were within the reference range. The formula with the highest ash content turned out to be B, with 3.70% (Table 7). In terms of RDA for total mineral, formulae A and E were the best. The presence of ash in the formulas is indicative of the presence of minerals in them, and hence the formulated complementary foods could be used in the fight against micronutrient deficiency in children. WHO recommends an ash content of 2.9g for every 100g of food sample for complementary foods, and the five formulas all have ash contents within this range, with some slightly higher, like formula B (the most preferred formula), whose ash content was up to 3.7%. Mahmoud and Mohammed (2014) found an ash content of 2.91% for their complementary food formulated from rice, sweet potatoes, faba beans and peanut oil, while Tiencheu et al. (2016) and Akinola et al. (2014) recorded higher ash contents (4.32% - 4.85% and 5.21%-7.52%, respectively) for their own formulations made out of egg whites, fermented maize, pawpaw and beans, guinea corn, millet, groundnuts, carrots and crayfish.

The fiber content of all the formulas was higher than the recommended value of 3.8% for complementary foods. However, there was no significant difference (P>0.05) between the fibre content of any of the formulas and the standard recommended value (3.8%) by WHO. The findings in this study were contrary to findings reported by Shewangzaw et al. (2021) from their complementary food formulas made from a mix of soybeans, teff, white maize and honey bee larvae, where they found much lower fibre contents in the range of 2.75% – 4.52%.

For protein contents, all samples had very high protein than the standard value of 15%, which is prescribed by WHO for complementary foods. This difference between the formulas and the standard value was however insignificant (P>0.05) for four out of five formulas. The lowest protein content was found in formula C (17.72%) and E (18.11%). The high protein content of the five formulas could be considered a good thing, since protein energy malnutrition rates are still so high in Africa. Mahmoud and Mohammed (2014) found a 7.48% and 4.94% protein content for rice and sweet potato flours respectively, implying that rice has more crude proteins than sweet potatoes. The germination and malting of the maize used in this study improved on its protein content, making the blend with maize as main starch source to have the second highest protein content, after the one with rice.

The results obtained from the analysis of the fat content of the formulas showed them having fat contents in the range 9.5% - 14%, all of which are above the reference value of 8%. The only formula which showed a statistically significant difference ($P<0.05$) between its fat content and the standard value was formula D. The lowest fat content was recorded in E (9.5%), though this was still higher than the reference (Table 7). A higher fat content could be a good, as well as it could increase the energy density of food; but must decrease it shelf live. Aduni et al. (2016) found fat contents in the range of 3.15% to 14.35% for their nine instant weaning foods made out of crayfish, carrot, irish potatoes, soybeans and Ndop rice.

The carbohydrate contents were all lower than the standard value of 64.68%, with the least content obtained from B (38.74%), and the highest from C (63.58%) (Table 7). Anigo et al. (2010) obtained dissimilar results for carbohydrate content from their formula (88.75% - 90.89%) which was a blend of soybeans, groundnuts, guinea corn, sorghum, corn and millet in different proportions.

Table 7: Proximate Analysis of the Formulae

Samples	Ash Content (%)	Fibre Content (%)	Protein Content (%)	Fat Content (%)	Carbohydrate. Content (%)	Energy Content (Kcal)
WHO standard	**2.9**	**3.8**	**15**	**8**	**64.68**	**400**
Formula A	$2.65±0.15^a$	$7.13±1.43^a$	$25.82±3.07^a$	$11.00±1.00^a$	$53.14±2.92^a$	$414.8±8.40^a$
Formula B	$3.70±0.40^a$	$7.32±1.42^a$	$37.72±9.54^b$	$11.50±0.50^a$	$38.74±8.49^b$	$409.3±0.30^a$
Formula C	$3.10±0.00^a$	$7.29±0.73^a$	$17.72±0.66^a$	$11.00±2.00^a$	$63.58±2.04^a$	$433.2±1.80^b$
Formula D	$2.95±0.05^a$	$6.43±2.23^a$	$20.13±0.44^a$	$14.00±0.00^b$	$56.53±0.29^a$	$432.6±0.60^b$
Formula E	$2.65±0.05^a$	$9.27±0.15^a$	$18.11±1.05^a$	$9.50±0.50^a$	$59.24±1.50^a$	$394.9±2.70^a$

The superscripts a = statistical significance at $p < 0.05$ and b = significance at $p < 0.01$ compare to WHO reference pattern value

The energy content of the five formulas, which is a function of the carbohydrate, fat and protein content of each one of them, was higher than the recommended value of 400Kcal for four out of the five formulas., it was noted that apart from formula E whose energy content was below (394.9Kcal) the reference value of 400Kcal, all other formulas had energy contents above this standard value (Table 7). Comparing these values with the standard value showed no statistically significant difference ($P>0.05$) between formulas A, B, E and the standard, while formulas C and D showed statistically significant differences from the standard ($P<0.05$). Araro et al. (2020) got similar results in their complementary food mixes made with sweet potatoes, brown teff, and dark red kidney beans. Their mixes had energy levels in the range of 339.07% - 356.74%, values which were all slightly lower than the recommended value. The high energy levels of the five formulas, which are as a result of high protein, carbohydrate and fat levels, makes them a suitable complementary food to overcome the deficit that may have been caused by climate change and environmental challenges.

Micronutrient Analysis

Table 8 gives a summary of minerals analyses of the five formulae, pap and the WHO standard values for each of these micronutrients. From the mineral analysis of the samples, the calcium content of the formulas was above the reference value (341.2mg/100g). This difference was however, not statistically significant (P>0.05), except for formula B. Among the five formulas, formula B, whose main starch source was rice, had the highest calcium content (632mg/100g), followed by C with 454mg/100g of calcium, then formulas D and E with calcium contents of 408.0mg/100g. It is of utmost importance that the novel formulas are up to standard with their calcium content, as calcium is extremely important for the brain and bone development of the infant. Plahar (2018) found similar results for his sweet potato-based formulas which contained groundnuts (357.89mg/100g-256.57mg/100g)), but lower calcium content (100.73-91.96mg/100g) in similar sweet potato-based formulas which did not contain groundnuts. Ajiwe and Nwaigbo (2014) had dissimilar results in their formulas made from different proportions of yellow maize, millet, red sorghum, wheat, brown spotted African yam bean, bambara groundnut, pigeon pea and soybeans (42.19 – 140.76mg/100g).

The iron content of the formulas ranged from 4.73mg/100g (formula E) to 8.59mg/100g (Formula C). They were generally lower than the reference value of 8.5mg/100g, except C, with sweet potatoes as main starch source, which had an iron content of 8.59mg/100g. This could be explained by the fermentation process done on the corn, since fermentation has been shown to enhance the bioavailability of several micronutrients which are usually coupled to phytates in the unfermented grains. Satter et al. (2014) found similar results from their complementary food formulated from wheat, soybeans, sugar, mango, skimmed milk and jackfruit. They had values for iron content in the range of 7.56 - 8.22mg/100g. Ikujenlola and Adurotoye (2014) had much higher values of iron content (260-390mg/100g) in their complementary food formulated from high protein maize and steamed cowpea. The infant's daily requirements for iron are met, as the role of iron in the body is very vital in malaria endemic zone like Cameroon, and it is important that its RDA is always met.

The WHO standard for phosphorous, in a complementary food, is set at approximately 100mg/100g. All five formulas were found to be higher in phosphorous than the standard value; with C having the highest phosphorous content (136.49mg/100g), followed by A with a content of 119.28mg/100g. The range of phosphorous values were from 109.04-136.49mg/100g, with formula C, containing sweet potato as main starch source, having the highest phosphorous content. Except for formula C, the difference in phosphorous content between the standard values and the values obtained in the formulas was not statistically significant (P>0.05). Tiencheu et al. (2016) had much higher values (286.37-365.08mg/100g) for phosphorous in their complementary food formulated from maize, pawpaw, red beans and mackerel fish meal, same as Anigo et al. (2010) who had higher values in the range of 148.98 – 219.98mg/100g in their formulations made from guinea corn, sorghum, maize, millet, soybeans and groundnuts.

The analysis of zinc content revealed that all five samples were lower than the recommended value of 3.7mg/100g set by the WHO. The range of zinc content of the five samples was 1.47mg/100g to 2.35mg/100g. This difference between the standard value and the values obtained from the samples was statistically significant ($P<0.05$) for two out of five samples (C and D), but not statistically significant for the other three formulas (A, B and E). Among the five formulas, formula A was richest in zinc (2.35mg/100g), followed by B with 2.32mg/100g. Gemede et al. (2020), had slightly higher values, in the range of 2.73 – 3.00 mg/100g for zinc content of their complementary food formulated from maize, pea and anchote flours, while Asouzu and Nkemjika (2020) had similar results ranging from 1.52-2.61mg/100g in their complementary food formulated with maize and supplemented crayfish and carrot flour.

The analysis of magnesium content of the five samples showed that the two formulas with the highest magnesium contents were C (85.19mg/100g) and H (75.75mg/100g). Formula B had a magnesium content of 72.91mg/100g, while A had 70.6mg/100g. The least formula was D, with 58.32mg of magnesium per 100g of formula. The WHO standard for magnesium in complementary foods is 48.7mg/100g, and this standard was clearly met and surpassed by all five samples, though the difference was statistically insignificant ($P>0.05$) for all five samples. Bolarinwa et al. (2019) had dissimilar values, ranging from 0.21- 0.24mg/100g while Mohammed et al. (2021) had similar results of magnesium content, a value of 54.44mg/100g for their complementary food mix made up of an improved variety of yellow maize, soybeans and African catfish meal.

The sodium content of the five formulas was analyzed and it was realized that there was a statistically significant difference ($P<0.01$) between four of the formulas (B, C, D and E) and the reference value of 60mg/100g. Only formula A had no statistically significant difference with the reference value. For the five formulas, the sodium content ranged from 102.42mg/100g (formula A) to 189.41mg/100g for formula B. Also, the analysis of potassium content revealed that formulas B, D and E had similar potassium contents (611.49mg/100g), and this was the highest value observed among the five formulas; C had a potassium content of 728.82mg/100g, while A had least value (319.2mg/100g). The recommended value for potassium for a complementary food is 408.7mg/100g. Apart from formula A whose value for potassium content was below standard, all the other formulas had higher than the standard values for potassium content. Aduni et al. (2016), on the other hand, had similar results for sodium and potassium contents for their complementary foods, with sodium ranging from 74.50 – 88.17, and potassium from 241.87 – 1322.27mg/100g. The most preferred formula (B) had the highest sodium content and satisfactory potassium content as well. Solomon (2005) obtained values of 11.1-21.1mg/100g for sodium content, and 99.7 to 129.7mg/100g of potassium for a complementary food based on rice, maize, acha grains, soybeans, groundnuts, bambara nuts and crayfish, both of which were below the standard.

This section showed that infant’s micronutrients requirements in terms of recommended dietary allowance (RDA) that cannot be covered due to climate change consequences on food composition, and can be improved through dietary diversification, fermentation, germination and food formulation strategies applied in this study. Such mitigation techniques need to be encouraged and promoted.

Table 8: Micronutrient Analysis of the Formulated Complementary Foods

SAMPLES	WHO standard	Formula A	Formula B	Formula C	Formula D	Formula E
Ca (mg/100g)	**341.2**	378.0±14.0^a	632.0±12.0^b	454.0±2.0^a	408.0±16.0^a	408.0±16.0^a
Fe (mg/100g)	**8.5**	6.03±0.21^a	6.27±1.3^a	8.59±2.7^a	6.30±0.8^a	4.73±0.3^a
P (mg/100g)	**100**	119.28±8.8^a	109.98±2.3^a	136.49±8.4^b	114.63±1.4^a	109.04±10.7^a
Zn (mg/100g)	**3.7**	2.35±0.63^a	2.32±0.37^a	1.56±0.06^b	1.47±0.18^b	1.87±0.28 ^{a}
Mg(mg/100g)	**48.7**	70.6±21.74^a	72.91±9.73^a	85.19±12.01^a	58.32±9.72^a	75.75±6.31^a
Na (mg/100g)	**60**	102.42±0.0^a	189.41±14.2^c	162.02±13.18^b	136.72±12.13^b	136.72±12.13^b
K (mg/100g)	**408.7**	319.2±0.0^b	611.49±22.5^c	728.82±0.0^c	611.49±22.5^c	611.49±22.5^c

The superscripts a = statistical significance at $p < 0.05$, b = significance at $p < 0.01$ and c = significance at $P < 0.001$, compared to WHO reference pattern value.

Conclusion

The impacts of climate change are perceptible in the South West region and are likely to be greater in areas with existing poor food security, as the nutrient content from 1966 to 2022 were noted here after a period of 55 years. Therefore, government and organisations need to put more financial and technical support toward adaptation in least developed countries, as currently, financial contributions remain insufficient to meet adaptation needs. Nutrient enhancement strategies should be vulgarised and promoted through training of trainees. We therefore recommend that nutritional education campaigns should be organised at community levels to empower the key actors, with practices (diversification and fortification) before 2030; Additionally, Green Climate Eco-nutritional fund should be created to encourage efforts of developing countries in responding to the challenge of climate change. Immediate additional public funding is required in order to support these adaptive strategies of the world's poorest to climate change. Better nutritional health can improve the resilience of a population to climate-related shocks and stresses. Governments and donors should support nutrition focused adaptation and Disaster Risk Management strategies and target women and children most at risk for under-nutrition as a priority. Guaranteeing food and nutritional security should be a priority for donors that finance adaptation measures. Therefore, these findings may contribute to effort geared toward Cameroon's attaining the SDG's, notably SDG 3 on health and wellbeing, SDG 13 on climate change and SDG 2, zero hunger.

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