Online ISSN : 2249-4618
Print ISSN : 0975-5888
DOI : 10.17406/GJMRA

Global Journal

of Medical Research: L

Nutrition and Food Science

Highlights

Microbial Load of Sliced Cardiometabolic Biological Risk Factors

Ekerenyo Sub-County Hospital Predictors of Malnutrition among Children

Discovering Thoughts, Inventing Future

VOLUME 21 ISSUE 1 VERSION 1.0

Global Journal of Medical Research: L
Nutrition & Food Science

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Nutrition & Food Science

Volume 21 Issue 1 (Ver. 1.0)

Open Association of Research Society

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USA Tax ID: 98-0673427

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Global Journal of Medical Research: L
Nutrition & Food Science
Volume 21 Issue 1 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

Cardiometabolic Biological Risk Factors, Unhealthy Lifestyle, and Antipsychotic Drug use among People with Psychotic Disorders in Cameroon

By Hermine Raissa Hell, Maxwell Nguedjo Wandji, Boris Ronald Tchuente Tonou, Celine Sylvie Mimboe Bilongo, Hippolyte Tene Mouaf, Abomo Anne-Christine Ndzana, Jean Pierre Olen Kamga & Olga Yvonne Mankollo Bassong

University of Yaounde

Abstract- *Background:* The aim of this study was to assess the prevalence of cardiometabolic risk factors and examine whether the presence of metabolic abnormalities is associated with antipsychotic drug use andthe lifestyle of patients with psychotic disorders.

Methods: This study was cross-sectional and was carried out at the Jamot Hospital in Yaounde (Cameroon), on patients with psychotic disorders and under treatment. Parameters performed on participants were physical examination and fasting glucose.

Keywords: *cardiometabolic biological risk factors, unhealthy lifestyle, antipsychotic drugs, psychotic disorders.*

GJMR-L Classification: *NLMC Code: WM 200*

Strictly as per the compliance and regulations of:

Cardiometabolic Biological Risk Factors, Unhealthy Lifestyle, and Antipsychotic Drug use among People with Psychotic Disorders in Cameroon

Hermine Raissa Hell [α], Maxwell Nguedjo Wandji [σ], Boris Ronald Tchuente Tonou [ρ], Celine Sylvie Mimboe Bilongo [ω], Hippolyte Tene Mouafo[¥], Abomo Anne-Christine Ndzana[§], Jean Pierre Olen Kamga [χ] & Olga Yvonne Mankollo Bassong [ν]

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Methods: This study was cross-sectional and was carried out at the Jamot Hospital in Yaounde (Cameroon), on patients with psychotic disorders and under treatment. Parameters performed on participants were physical examination and fasting glucose. Some information on the participants, such as antipsychotic therapy, physical activity, smoking, and fruit/vegetable consumption, were collected.

Results: Among the 82 patients involved in the study and with a mean age of 32.7±10.73 years, 35.4% were overweight, 18.3% were obese, and 41.1% had abdominal obesity. Women were more affected by overweight and obesity compared to men ($p < 0.05$). The prevalence of hypertension was 54.9%, and of hyperglycemia was 42.7%. Low physical activity was significantly associated with the risk of being overweight (OR=5.92; CI 1.86-18.84). Atypical antipsychotic drug use increased the risk of overweight, obesity, and hyperglycemia. Smoking was associated with the risk of hyperglycemia and hypertension.

Conclusion: This study found a high prevalence of cardio metabolic biological risk factors, associated with unhealthy lifestyles and antipsychotic medication.

Keywords: cardiometabolic biological risk factors, unhealthy lifestyle, antipsychotic drugs, psychotic disorders.

I. Introduction

Cardiovascular diseases are known as one of the most common causes of premature death and great health concerns [1]. These diseases affect all classes of the population. However, recent studies show that they are higher in patients suffering from psychotic disorders than in the general population [2]. This high CVD rate contributes significantly to impair health status and reduces life expectancy, resulting in early death in people with psychosis [3]. From an epidemiological perspective, the increased prevalence of CVD might associated with cardiometabolic biological risk factors such as hypertension, hyperglycemia, dyslipidemia, and obesity [4]. These metabolic abnormalities might also be influenced by psychiatric conditions and an unhealthy lifestyle characterized by a high-calorie diet high in saturated fat, tobacco and alcohol consumption, and lack of physical exercise [5,6]. However, other factors such as antipsychotic medications may also exacerbate the onset of metabolic disorders, with significant weight gain, lipid disorders, and alterations in blood glucose levels [7]. Indeed, numerous studies have shown that people with psychotic disorders and under treatment have a substantial risk of death due to CVD [8] and an increased risk of developing diabetes, hypertension, and hyperlipidemia [9]. A meta-analysis revealed a prevalence of 44% abdominal obesity, 19.5% hyperglycemia, and 39% hypertension among people with psychotic disorders worldwide [10].

In sub-Saharan Africa, the prevalence of cognitive impairment in the population was between 6.3% and 25% [11], and of dementia between 2.29% and 21.60% [12]. It suggests that the population of African countries and particularly those from Cameroon are not free from this scourge [13]. However, developing an effective control strategy requires scientific data on the cardiometabolic of cardio metabolic risk factors in patients with psychotic disorders and the determinants of their progression specific to the socio-cultural context. Thus, it is of concern that cardiovascular disease is not well described in this population and the low rate of metabolic screening. Therefore, to fill these gaps, our study aims to determine the prevalence of cardio metabolic risk factors and examine whether or not the

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presence of metabolic abnormalities is associated with antipsychotic drug use and lifestyle in this vulnerable population.

II. Materials and Methods

a) Study design and Recruitment

A cross-sectional and descriptive study carried on throughout January 2018 in the psychiatric ward of the Jamot Hospital in Yaoundé, (Central Region of Cameroon), which is a reference hospital for psychiatry in Cameroon. Patient recruitment was based on antipsychotic drugs, the absence of mental instability, and the absence of a diabetogenic diagnosis before the start of treatment. A total of 82 patients of both sexes, aged at least 18 years and suffering from psychotic disorders, were selected.

b) Ethical Consideration

The study was approved by the National Ethics Committee for Research in Human Health of Cameroon under N°2017/0588/CEIRSH/ESS/MSP and it was authorized by the Director of Jamot Hospital, Yaoundé under the reference n°00001731/MINSANTE/SG/DHJY. Free and informed consent was obtained from each patient, or their parent or legal guardian to participate in the study. The study was carried on in strict compliance with medical ethics following the Declaration of Helsinki.

III. Data Collection

a) Questionnaire

After obtaining free and voluntary consent from the participants involved in this study, well-structured questionnaires were administered by well-trained health staff. The questionnaire was adapted from the WHO Stepwise approach for surveillance of risk factors for nutrition-related chronic disease-Instrument V2.1. Participants' information on age, sex, consumption of tobacco, alcohol, fruits, and vegetables, and the antipsychotic drugs administered were collected. Antipsychotic drugs were grouped into two types: typical antipsychotics and atypical antipsychotics. Alcohol and tobacco consumption was classified into two categories: non-drinkers and drinkers and non-smokers and smokers, respectively. The participant's consumption of carried on and vegetables was grouped based on weekly intake. From 0 to 1 time per week, was classified as irregular; ≥ 2 times/week, it was classified as regular. Based on the WHO Global Physical Activity Questionnaire (GPAQ) Analysis Guide, participants were classified as having low and high levels of physical activity by using the information related to their principal activity at work, transportation, leisure activities, and sitting.

IV. Measurements

a) Anthropometric measurements

Participants Weight was measured to the nearest 0.1 kg using a TANITA™ personal scale. Their Height was recorded using a SECA vertical scale graduated to the nearest centimeter. Body mass index (BMI) was calculated as weight using the formula: BMI = Weight (kg)/Height^2 (m) and expressed in kg/m^2. The waist circumference was measured using a tape on the midpoint between the lower rib margin and the iliac crest in a perpendicular plane to the long axis of the body without restrictive garments.

b) Arterial blood pressure measurements

Blood pressure was measured using an OMRON electronic radial sphygmomanometer at rest. The participant was seated in a chair with the left arm parallel to the heart. The measurement was taken at the beginning of the interview after a 10-minute rest. The values obtained on the dial of the device were used to assess the presence or absence of hypertension.

c) Biochemical Analysis

Fasting blood glucose was measured by the glucose oxidase method of Trinder [14] using a glucose meter and test strips (Gluco Plus®) directly on the participant's fingertip.

d) Diagnosis of cardiometabolic risk factors

Nutritional status has been defined according to WHO criteria as follows: overweight has been defined as a BMI between 25 and 29.9 kg/m^2 and has as a BMI ≥ of 30 kg/m^2 [15]. Other metabolic abnormalities were diagnosed according to the criteria of the National Cholesterol Education Program Adult Treatment Panel III as follows: Abdominal obesity, determined by high waist circumference (>102 cm for men and>88 cm for women); Hyperglycemia, (fasting blood glucose≥110 mg/dL) and Hypertension, (high blood pressure: Systolic Blood Pressure (SBP)≥130 mmHg and Diastolic Blood Pressure (DBP) ≥ 85 mmHg) [16].

e) Statistical analysis

The data was analyzed using SPSS version 25.0 for Windows. The results were showed as a mean ± standard deviation (SD) for continuous variables and as a frequency (%) for categorical variables. The Pearson chi-square test was used to compare proportions between categorical variables. The student's t-test was used to detect differences in between two groups of a continuous dependent variable. Bivariate logistic regressions were used to assess the risk of developing metabolic abnormalities. The significance level used was $p<0.05$.

V. Results

The study population included 82 patients with psychotic disorders of which 41 were women and 41

men. The clinical characteristics of the study population were presented in Table 1. The mean BMI of participants was significantly ($p<0.05$) higher in women (28.72±5.56 kg/m^2) than in men (23.89±3.45 kg/m^2). A similar observation was noticed with the waist circumference of females (96.93±14.74 cm) than in males (88.54±12.97 cm). At the same time, the mean height was significantly higher in men (1.72±0.09 m) than in women (1.67±0.10 m) ($p<0.05$). However, no significant difference was noticed between men and women considering the means of age, weight, fasting blood glucose, systolic blood pressure, and diastolic blood pressure.

Table 1: Clinical characteristics of the study population

Parameters	Population	Women	Men	P-value
Age (years)	32.70±10.73	33.07±9.67	32.32±11.81	0.752
Weight (kg)	75.82±14.38	78.83±15.88	72.80±12.16	0.057
Height (m)	1.72±0.11	1.67±0.10	1.72±0.09	0.0001*
BMI (kg/m^2)	26.30±5.20	28.72±5.56	23.89±3.45	0.0001*
WC (cm)	92.73±14.43	96.93±14.74	88.54±12.97	0.008*
Blood glucose (mg/dL)	108.26±23.93	104.83±22.84	111.68±24.78	0.197
SBP (mmHg)	132.51±25.19	131.71±20.84	133.32±29.13	0.774
DBP (mmHg)	80.41±14.66	79.66±16.09	81.17±13.22	0.643

*BMI=body mass index, WC=Waist circumference, SBP=systolic blood pressure, DBP=diastolic blood pressure, *=significant difference.*

As shown in Table 2, the prevalence of overweight and obesity was significantly higher in women (48.8% and 29.3%) than in men (22% and 7.3%, respectively) Furthermore, the prevalence of hyperglycemia was significantly higher in men (53.7%) then in women (31.7%). In the general population, 35.4% (n=29) of participants were overweigh (25≤ BMI≤29kg/m^2), 18.3% (n=15) were obese (BMI ≥ 30kg/m^2) and 42.7% (n=35) had hyperglycemia. However, high blood pressure was more prevalent in the general population 54.9% (n=45), with systolic hypertension predominating 48.8% (n=40).

Table 2: Prevalence of cardiometabolic biological risk factors in the population

Biological factors	Population %(n)	Women %(n)	Men %(n)	P-value
Overweight(25≤ BMI≤29kg/m^2)	35.4(29)	48.8(20)	22.0(9)	0.0001*
Obesity(BMI ≥ 30kg/m^2)	18.3(15)	29.3(12)	7.3(3)	0.0001*
Abdominal obesity	41.5(34)	36.6(15)	46.3(19)	0.370
Hyperglycemia	42.7(35)	31.7(13)	53.7(22)	0.044*
Systolic hypertension	48.8(40)	51.2(21)	46.3(19)	0.659
Diastolic hypertension	46.3(38)	41.5(17)	51.2(21)	0.376
Hypertension	54.9(45)	53.7(22)	56.1(23)	0.824

The majority of the study population was sedentary (63.4%) and women were less active than men (82.9% vs. 43.9%) (Table 3). The prevalence of Tobacco and alcohol consumption was 39% and 58.5%, respectively in the general population and the highest consumption scores were recorded with men 48.8% and 63.4% for tobacco and alcohol, respectively. 50% of the participants had an irregular consumption of fruit/legumes. This irregular consumption was more pronounced among women (51.2%).

Table 3: Prevalence of unhealthy lifestyle factors in the population

Factors of unhealthy lifestyle	Population %(n)	Women %(n)	Men %(n)	P-value
Consumption of tobacco	39.0(32)	29.3(12)	48.8(20)	0.070
Consumption of alcohol	58.5(48)	53.7(22)	63.4(26)	0.370
Irregular consumption of fruit/vegetable	50.0(41)	51.2(21)	48.8(20)	0.825
Low level of physical activity	63.4(52)	82.9(34)	43.9(18)	0.0001*

Table 4 shows that participants under atypical antipsychotic medication were more affected by overweight (46.4%), obesity (28.6%), and hyperglycemia (57.1%) regardless of gender. Patients under typical

antipsychotic medication were more significantly ($p<0.05$) affected by systolic hypertension (61.1%), diastolic hypertension (59.3%), and high blood pressure (66.7%). Also, gender was an significant factor in each category.

Table 4: Type of antipsychotic medication and prevalence of cardiometabolic biological risk factors in the study population

	Typical antipsychotic				atypical antipsychotic				P-value t*a
Biological risk factors	Population %(n)	Women %(n)	Men %(n)	P-value	Population %(n)	Women %(n)	Men %(n)	P-value	
Overweight(25≤ BMI≤29kg/m^2)	29.6(16)	37.5(9)	23.3(7)	0.013 *	46.4(13)	64.7(11)	18.2(2)	0.001 *	0.017*
Obesity(BMI ≥ 30kg/m^2)	13.0(7)	25(6)	3.3(1)	0.013 *	28.6(8)	35.3(6)	18.2(2)	0.001 *	0.005*
Abdominal obesity	42.6(23)	37.5(9)	46.7(14)	0.498	39.3(11)	35.3(6)	45.5(5)	0.591	0.773
Hyperglycemia	35.2(19)	16.7(4)	50.0(15)	0.011 *	57.1(16)	52.9(9)	63.6(7)	0.576	0.057
Systolic hypertension	61.1(33)	66.7(16)	56.7(17)	0.454	25(7)	29.4(5)	18.2(2)	0.503	0.002*
Diastolic hypertension	59.3(32)	58.3(14)	60.0(18)	0.901	21.4(6)	17.6(3)	27.3(3)	0.544	0.001*
Hypertension	66.7(36)	66.7(16)	66.7(20)	1.000	32.1(9)	35.3(6)	27.3(3)	0.657	0.003*

*P-value t*a: p-value observed for comparison between patients on typical and atypical antipsychotics*

Table 5 shows that participants on typical antipsychotics consumed significantly more alcohol (68.5%) than those on atypical antipsychotics (39.3%). Moreover, regardless of antipsychotic treatment, women were significantly less active than men ($p < 0.05$).

Table 5: Type of antipsychotic and prevalence of unhealthy lifestyle factors in the study population

	Typical antipsychotic				Atypical antipsychotic				P-value t*a
Factors of unhealthy lifestyle	Population %(n)	Women %(n)	Men %(n)	P-value	Population %(n)	Women %(n)	Men %(n)	P-value	
Consumption of tobacco	42.6(23)	29.2(7)	53.3(16)	0.074	32.1(9)	29.4(5)	36.4(4)	0.700	0,358
Consumption of alcohol	68.5(37)	66.7(16)	70.0(21)	0.793	39.3(11)	35.3(6)	45.5(5)	0.591	0.011*
Irregular consumption of fruits/vegetable	51.9(28)	54.2(13)	43.3(13)	0.429	46.4(13)	47.1(8)	63.6(7)	0.390	0.641
Low level of physical activity	59.3(32)	79.2(19)	43.3(13)	0.008 *	71.4(20)	88.2(15)	45.5(5)	0.014 *	0.278

*P-value t*a: p-value observed for comparison between patients on typical and atypical antipsychotics*

Table 6 presents the occurrence risk of cardio metabolic biological risk factors associated with using a type of antipsychotic drug. The use of the atypical antipsychotic drug increased the risk of overweight (OR=3.59; 95% CI: 1.19-10.80), obesity (OR=5.06; 95% CI: 1.37-18.65), and hyperglycemia (OR=2.45; 95% CI: 0.96-6.24).

Tableau 6: Bivariate logistic regression showing the association of cardiometabolic biological risk factors and the use of antipsychotic drugs.

Biological risk factors	Treatment with antypsychotics		
	Typical reference	Atypical OR (95%)	P-value
Overweight(25≤ BMI≤29kg/m^2)	1	3.59 (1.19-10.80)	0.022*
Obesity(BMI ≥ 30kg/m^2)	1	5.06 (1.37-18.65)	0.015*
Abdominal obesity	1	0.87 (0.34-2.21)	0.872
Hyperglycemia	1	2.45 (0.96-6.24)	0.059
Systolic hypertension	1	0.21 (0.07-0.58)	0.003*
Diastolic hypertension	1	0.18 (0.06-0.53)	0.002*
Hypertension	1	0.23 (0.08-0.62)	0.004*

The influence of an unhealthy lifestyle on the risk of developing metabolic pathologies is illustrated in Table 7. Globally, tobacco consumption increased the risk of developing hyperglycemia (OR=2.01; 95% CI: 0.81-4.97); diastolic hypertension (OR=1.92; 95% CI: 0.78-4.73) and hypertension (OR=1.34; 95% CI: 0.55-3.31). A sedentary lifestyle increased the risk of being overweight (OR=5.92; 95% CI: 1.86-18.84) and obese (OR=3.39; 95% CI: 0.91-12.60). However, the consumption of alcohol and the irregular consumption of fruit/vegetable does not influence the occurrence of cardio metabolic biological risk factors in the study population.

Table 7: Bivariate logistic regression model showing the association of cardiometabolic biological risk factors and the unhealthy lifestyle

Cardiometabolic biological risk factors	Tobacco consumption			Alcohol consumption			Consumption of fruit/vegetable			Level of physical activity		
	No ref	Yes OR (95%)	P-value	No ref	Drinkers OR (95%)	P-value	Regular ref	Irregular OR (95%)	P-value	Active ref	Inactive OR (95%)	P-value
Overweight (25≤ BMI≤29kg/m^2)	1	0.61 (0.22-1.63)	0.326	1	0.64 (0.23-1.72)	0.378	1	0.84 (0.31-2.21)	0.724	1	5.92 (1.86-18.84)	0.003*
Obesity(BMI ≥ 30kg/m^2)	1	0.15 (0.03-0.77)	0.023*	1	0.45 (0.13-1.53)	0.204	1	0.78 (0.23-2.60)	0.696	1	3.39 (0.91-12.60)	0.067
Abdominal obesity	1	0.61 (0.24-1.53)	0.299	1	0.67 (0.27-1.64)	0.388	1	1.00 (0.41-2.40)	1.000	1	1.10 (0.44-2.74)	0.838
Hyperglycemia	1	2.01 (0.81-4.97)	0.128	1	0.73 (0.30-1.79)	0.501	1	0.73 (0.30-1.78)	0.503	1	0.77 (0.31-1.91)	0.580
Systolic hypertension	1	1.08 (0.44-2.63)	0.860	1	0.92 (0.38-2.21)	0.853	1	1.00 (0.42-2.37)	1.000	1	0.60 (0.24-1.50)	0.279
Diastolic hypertension	1	1.92 (0.78-4.73)	0.152	1	0.95 (0.39-2.29)	0.913	1	0.67 (0.28-1.61)	0.376	1	0.79 (0.32-1.95)	0.614
Hypertension	1	1.34 (0.55-3.31)	0.513	1	0.93 (0.38-2.25)	0.878	1	0.90 (0.38-2.16)	0.824	1	0.72 (0.29-1.79)	0.480

ref=reference

VI. Discussion

Cardiovascular diseases are known as one of the most common causes of premature death and great health concerns [1]. These cardiovascular diseases are due to a propensity for cardiometabolic risk factors. These can be exacerbated by a state of psychosis and a poor lifestyle [5,6]. This study aimed to determine the prevalence of cardiometabolic risk factors and examine whether the presence of metabolic abnormalities is associated with antipsychotic drug use or lifestyle in this vulnerable population.

The state of cardiometabolic risk factors in Cameroonian patients with psychotic disorders revealed that low physical activity was predominant in this population (63.4%). It could be due to the side effect of antipsychotic drugs, which included fatigue. Psychiatric symptoms and the severity of mental illness could also explain the participants' inactivity [17]. High levels of physical inactivity in mentally ill patients and under treatment were also observed by Nyboe and Lund [18]. Independently of the sensitization campaign on the side effects of tobacco and alcohol, it was found that 58.5 % of the subjects consumed alcohol and 39 % were smokers. The reason behind this could be the westernization of lifestyle habits and especially the popularisation of these products. However, the beneficial effect of the nicotine contained in tobacco on cognition and mood could also explain the fact that these persons with psychotic disorders often smoked tobacco [19]. An increase in tobacco and alcohol consumption among patients suffering from psychotic disorders than the general population was highlighted by Hartz et al. [20]. Half of the participants in this study had a low intake of fruits and vegetables. Indeed, low fruit and vegetable consumption associated with tobacco and alcohol consumption have been reported in people with psychosis [21]. Likewise, a low-fiber diet was found in these patients [22]. In general, low fruit and vegetable consumption accompanied by unhealthy behaviors have been observed in patients undergoing treatment with typical and atypical antipsychotic drugs. It would be attributed much more to the mental illness itself than to the use of antipsychotic medication.

Regarding cardiometabolic biological risk factors, 35.4% of patients were overweight, and 18.3% were obese. Overall, among the overweight or obese participants, the majority were women. An observation of the physical activity data also showed that women were more inactive. Therefore, women's physical inactivity may account for their high prevalence of obesity. Sultani et al. [23] also observed a significant association between low physical activity and obesity in people with psychotic illnesses. In this study, the irregular consumption of fruits and vegetables (less than once a week) by 50% of the participants could also justify the high prevalence of obesity. Indeed, high consumption of fruit will provide the body with dietary fiber which will increase satiety leading to a reduction in total energy intake and prevents weight gain [24]. On the other hand, the overweight observed in patients under antipsychotic drugs is probably secondary to an increase in food consumption due to the stimulant effect of the drugs. The action of antipsychotic drugs is believed to involve a blockade of dopamine and monoamine receptors leading to a potential increase in appetite with weight gain as an inference [25]. Sicras-Mainar et al. [26] showed that body mass index was significantly elevated in patients on antipsychotic medication and that obesity was associated with antipsychotic medication use. However, our results revealed that overweight was more prevalent among participants on atypical antipsychotic medication. This might be explained by the concomitant blocking of dopamine and serotonin receptors by atypical antipsychotics, which contribute to an increased risk of overweight and obesity, as opposed to typical antipsychotics that are more specific to dopamine receptors [27].

The occurrence of overweight due to the combined effect of low physical activity, antipsychotic medication, and a diet low in fruits and vegetables could also explain the presence of abdominal obesity in the participants via adipose tissue dysfunction leading to fat redistribution preferentially in the abdomen [28]. However, abdominal obesity was more prevalent in men (46.3%) than to women (36.6%) regardless of the type of antipsychotic drug administered. This could be explained by the heavy consumption of tobacco (48.8%) and alcohol (63.4%) in men. Nicotine is thought to affect fat distribution through its anti-estrogenic effect, which favors android-type fat distribution, and through the increase in stress hormones such as cortisol [29]. Also, alcohol consumption inhibits fat oxidation, thus promoting the accumulation and retention of lipids in visceral adipose tissue [30].

Participants were also affected by hyperglycemia (42.7%). Smoking in study patients could explain this abnormality in carbohydrate metabolism by inducing oxidative stress due to an increase in reactive oxygen species, be the cause of insulin resistance leading to the deregulation of blood glucose homeostasis [31]. It supports our results, which showed that tobacco consumption increased the risk of developing hyperglycemia by 2.01 times. However, men were more exposed to hyperglycemia (53.7%) than to women (31.7%). Smoking associated with the presence of more abdominal fat accumulation prevalent in men would be the cause. Indeed, it has been shown that abdominal obesity induces an excess of circulating free fatty acid, which is directly deleterious to insulin signaling, thus inhibiting GLUT4 translocation, resulting in the development of hyperglycemia [32] (Samaan et al., 2008). Besides, taking antipsychotics may indirectly

contribute to hyperglycemia through weight gain since excess body fat is known to be a risk factor for many metabolic disturbances such as hyperglycemia [33]. Indeed, Lorraine et al. [34] showed that patients under antipsychotic treatment were associated with a high risk of hyperglycemia.

Hypertension was the most prevalent cardiometabolic biological risk factor in this population (54.9%). This result could be explained by tobacco consumption, which exerts a persistent effect of pressure and tachycardia, by a mechanism that involves stimulation of the sympathetic nervous system with a consequent increase in blood pressure [35]. The high prevalence of hypertension could also be explained by the use of antipsychotic medication. Although the mechanisms by which antipsychotic drugs cause hypertension is not yet well understood, several studies have shown that patients on antipsychotic drugs (aripiprazole) have developed hypertension [36].

VII. Conclusion

This study revealed that Cameroonians with psychotic disorders are prone to cardiometabolic biological risk factors, including overweight, obesity, abdominal obesity, hypertension, and hyperglycemia. However, an unhealthy lifestyle characterized by low levels of physical activity and tobacco use, combined with antipsychotic medication, particularly atypical antipsychotics, contribute significantly to the occurrence of cardiometabolic biological risk factors. In light of these observations, it is important for healthcare providers to be aware of the potential cardiovascular adverse effects of antipsychotics and bad lifestyle behaviors, and to monitor and address Cardiometabolic biological risk factors in patients with psychosis. This study suggests that important steps should be taken by the government to reduce the morbidity and mortality of patients suffering from psychosis, and therefore consider the findings of this study to better improve the care and management of people suffering from psychosis in Cameroon. These measures should take into consideration the specific needs according to the socio-cultural context

Authors' Contributions

OYMB, KOJP, RHH designed and conducted the study; RHH collected the data; MWN, RBTT, and AACN conducted the statistical analysis of the data; MWN, RBTT, RHH, and CMSB wrote the manuscript. All authors read and approved the final manuscript.

Funding

This work has not been supported by a grant or funding.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this document.

References Références Referencias

1. Yuyun, M. F., Sliwa, K., Kengne, A. P., Mocumbi, A. O., & Bukhman, G. (2020). Cardiovascular Diseases in Sub-Saharan Africa Compared to High-Income Countries: An Epidemiological Perspective. *Global Heart,* 15(1): 15. DOI: https://doi.org/10.5334/gh.403
2. Sileshi, D. (2017). Cardiovascular disease among severe mental illness and psychiatric medication. *Global Journal of Medicine and Public Health,* 6(6): ISSN#-2277-9604.
3. Galletly, C. A., Foley, D. L., Waterreus, A., Watts, G. F., Castle, D. J., Mc Grath, J. J., Morgan, V. A. (2012). Cardiometabolic risk factors in people with psychotic disorders: The second Australian national survey of psychosis. *Australian & New Zealand Journal of Psychiatry,* 46(8), 753-761. doi:10.1177/0004867412453089
4. Mucheru, D., Hanlon, M-C., Campbell, L. E., Mc Evoy, M., & Mac Donald-Wicks, L. (2018). Cardiovascular disease lifestyle risk factors in people with psychosis: a cross-sectional study. *BMC Public Health,* 18(1). doi:10.1186/s12889-018-5649-5
5. Dipasquale, S., Pariante, C. M., Dazzan, P., Aguglia, E., McGuire, P., & Mondelli, V. (2013). The dietary pattern of patients with schizophrenia: A systematic review. *Journal of Psychiatric Research,* 47(2), 197-207. doi:10.1016/j.jpsychires.2012.10.005
6. Freyberg, Z., Aslanoglou, D., Shah, R., & Ballon, J. S. (2017). Intrinsic and Antipsychotic Drug-Induced Metabolic Dysfunction in Schizophrenia. *Frontiers in Neuroscience,* 11. doi:10.3389/fnins.2017.00432
7. Bruins, J., Jörg, F., Bruggeman, R., Slooff, C., Corpeleijn, E., & Pijnenborg, M. (2014). The Effects of Lifestyle Interventions on (Long-Term) Weight Management, Cardiometabolic Risk and Depressive Symptoms in People with Psychotic Disorders: A Meta-Analysis. *PLoS ONE,* 9(12), e112276.
8. Howell, S., Yarovova, E., Khwanda, A., & Rosen, S. D. (2019). Cardiovascular effects of psychotic illnesses and antipsychotic therapy. *British Medical Journal*, 0:1-8. doi:10.1136/heartjnl-2017-312107.
9. Liao, C.-H., Chang, C.-S., Wei, W.-C., Chang, S.-N., Liao, C.-C., Lane, H.-Y., & Sung, F.-C. (2011). Schizophrenia patients at higher risk of diabetes, hypertension, and hyperlipidemia: A population-based study. *Schizophrenia Research,* 126(1-3), 110-116. doi:10.1016/j.schres.2010.12.007
10. Mitchell A. J, Vancampfort D., Sweers, K., WinkelV. R., Yuw, De Hert M. (2013). Prevalence of metabolic syndromeand metabolic abnormalities in schizophrenia and related disorders–a systematic review and meta-analysis.Schizophrenia*Bulletin,*39, 306-318.

11. Mavrodaris, A., Powell, J., & Thorogood, M. (2013). Prevalences of dementia and cognitive impairment among older people in sub-Saharan Africa: a systematic review. *Bulletin of the World Health Organization,* 91(10), 773-783. doi:10.2471/blt.13.118422
12. Olayinka, O. O., & Mbuyi, N. N. (2014). Epidemiology of Dementia among the Elderly in Sub-Saharan Africa. *International Journal of Alzheimer's disease,* 2014, 1-15. doi:10.1155/2014/195750
13. Tianyi, F. L., Agbor, V. N., Njamnshi, A. K., & Atashili, J. (2019). Factors Associated with the Prevalence of Cognitive Impairment in a Rural Elderly Cameroonian Population: A Community-Based Study in Sub-Saharan Africa. *Dementia and Geriatric Cognitive Disorders,* 104-113.
14. Trinder P. Determination of glucose in blood using glucose oxidase with an alternative acceptor. *Ann. of clin. Biochem.*, 1959; 6: 24-27.
15. World Health Organization. (2003). Obesity, Prevention and Management of World Epidemy. Technical Reports Series, No. 916. World Health Organization, Geneva.
16. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. (2001). Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA,* 285, 2486-2497. https://doi.org/10.1001/jama.285.19.2486
17. Vancampfort, D., Firth, J., Schuch, F. B., Rosenbaum, S., Mugisha, J., Hallgren, M., Stubbs, B. (2017). Sedentary behavior and physical activity levels in people with schizophrenia, bipolar disorder and major depressive disorder: a global systematic review and meta-analysis. *World Psychiatry,* 16(3), 308-315. doi:10.1002/wps.20458
18. Nyboe, L., & Lund, H. (2012). Low levels of physical activity in patients with severe mental illness. *Nordic Journal of Psychiatry,* 67(1), 43-46. doi:10.3109/08039488.2012.675588
19. Aubin, H. J., Rollema, H., Svensson, T. H., & Winterer, G. (2012). Smoking, quitting, and psychiatric disease: a review. *Neuroscience and Biobehavioral Reviews,* 36(1), 271e284.
20. Hartz, S. M., Pato, C. N., Medeiros, H., Cavazos-Rehg, P., Sobell, J. L., Knowles, J. A., Pato, M. T. (2014). Comorbidity of Severe Psychotic Disorders with Measures of Substance Use. *JAMA Psychiatry, 71(3), 248.* doi:10.1001/jamapsychiatry.2013.3726
21. Hahn, L. A., Galletly, C. A., Foley, D. L., Mackinnon, A., Watts, G. F., Castle, D. J., Morgan, V. A. (2014). Inadequate fruit and vegetable intake in people with psychosis. *Australian & New Zealand Journal of Psychiatry,* 48(11), 1025-1035. doi:10.1177/0004867414553950
22. Brown, S., Birtwistle, J., Roe, L., Thompson, C. (1999). The unhealthy lifestyle of people with schizophrenia. *Psychol Med,* 29(3):697-701.
23. Suetani, S., Waterreus, A., Morgan, V., Foley, D. L.,Galletly, C., Badcock, J. C., McGrath, J. J. (2016). Correlates of physical activity in people living with psychotic illness. *Acta Psychiatrica Scandinavica,* 134(2), 129-137. doi:10.1111/acps.12594
24. Sharma, S. P., Chung, H. J., Kim, H. J., & Hong, S. T. (2016). Paradoxical Effects of Fruit on Obesity. Nutrients. 633(8), 1-16. doi:10.3390/nu8100633
25. Silverstone, T., Smith, G., & Goodall, E. (1988). Prevalence of Obesity in Patients Receiving Depot Antipsychotics. British *Journal of Psychiatry,* 153(02), 214-217. doi:10.1192/bjp.153.2.214.
26. Sicras-Mainar, A., Navarro-Artieda R., Rejas-Gutiérrez J., Blanca-Tamayo M. (2008). Relationship between obesity and antipsychotic drug use in the adult population: A longitudinal, retrospective claim database study in Primary Care settings. *Neuropsychiatric Disease and Treatment,* 4(1), 219-226.
27. Liberty, F. I., Todder, D., Umansky, R., Harman-Boehm, I. (2004). Atypical Antipsychotics and Diabetes Mellitus: An Association. *IMAJ*. 6: 276-279.
28. [28] Longo, M., Zatterale, F., Naderi, J., Parrillo, L., Formisano, P., Raciti, G. A., Miele, C. (2019). Adipose Tissue Dysfunction as Determinant of Obesity-Associated Metabolic Complications. *International Journal of Molecular Sciences,* 20(9), 2358. doi:10.3390/ijms20092358
29. Clair, C., Chiolero, A., Faeh, D., Cornuz, J., Marques-Vidal, P., Paccaud, F., Vollenweider, P. (2011). Dose-dependent positive association between cigarette smoking, abdominal obesity and body fat: cross-sectional data from a population-based survey. *BMC Public Health,* 11(1). doi:10.1186/1471-2458-11-23
30. Schröder, H., Morales-Molina, J. A., Bermejo, S., Barral, D., Mándoli, E. S., Grau, M., arrugat, J. (2007). Relationship of abdominal obesity with alcohol consumption at population scale. *European Journal of Nutrition*, 46(7), 369-376.doi:10.1007/s00394-007-0674-7
31. Sari, M. I., Sari N., Darlan D. M., Prasetya R. J. (2018). Cigarette Smoking and Hyperglycaemiain Diabetic Patients. *Open Access Macedonian Journal of Medical Sciences.*140, 1-4.
32. Samaan, C., & Amira, K.P. (2008). Obesity, insulin resistance and type 2 diabetes: the interaction between fat cells and muscle cells. Proceedings of scientific conferences of the *Endocrinology and Metabolism Directorate*. Vol. 8(7).

33. Han, T., Williams, K., Sattar, N., Hunt, K., Lean, M., Haffne, R. S. (2002). Analysis of obesity and hyperinsulinemia in the development of metabolic syndrome: San Antonio Heart Study. *Obes. Res.* 10: 923-931.
34. Lorraine, L. L.; Linda, L. V., Andrea, G., Hadasv, D. F., David, N. J., Sudeep, S. G., Nathan, H., Janet, E. H., Geoff, M. A., Paula, A. R. (2009). Antipsychotic Drugs and Hyperglycemia in Older Patients with Diabetes. *Arch Intern Med,* 2009; 169(14): 1282-1289.
35. Virdis, A., Giannarelli, C., Fritsch Neves, M., Taddei, S., & Ghiadoni, L. (2010). Cigarette Smoking and Hypertension. *Current Pharmaceutical Design,* 16(23), 2518-2525.doi:10.2174/138161210792062920
36. Alves, B. B.; Oliveira, G. D. P.; Neto, M. G. M.; Fiorilli, R. B.; and Cestário, E. D. E. S. (2019). Use of atypical antipsychotics and risk of hypertension: A case report and review literature. *SAGE Open Medical Case Reports* Volume 7: 1-6.

Global Journal of Medical Research: L
Nutrition & Food Science
Volume 21 Issue 1 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

Prioritizing Achievable Goals for Food Security in the Developing World

By Sanjaya Rajaram & Maarten van Ginkel

Abstract- Many solutions have been proposed to address food security. We present here a prioritized set of actions achievable within the next 2–10 years. By taking a systems approach we follow the impact pathway backwards starting from the needs and desires of the end-users to eventually define the research agenda that will exactly address those targeted solutions with positive impacts. The following actions emerge as high-priority and achievable in the near future: new research tools to study food systems; dis-aggregated intra-household surveys to reveal within-family inequalities in food access; increased scientific consensus on climate change impacts in sub-Saharan Africa; rapid response measures to address sudden emergencies, such as capturing excess rainfall water; financial tools to enable rapid responses with recovery measures afterwards; consideration of restrictions that excess heat and humidity impose on human productivity; secure land ownership and tenure rights to encourage long-term agricultural investment; mechanization at all stages along the food system.

GJMR-L Classification: *NLMC Code: WA 695*

Strictly as per the compliance and regulations of:

Prioritizing Achievable Goals for Food Security in the Developing World

Sanjaya Rajaram [α] & Maarten van Ginkel [σ]

Abstract- Many solutions have been proposed to address food security. We present here a prioritized set of actions achievable within the next 2–10 years. By taking a systems approach we follow the impact pathway backwards starting from the needs and desires of the end-users to eventually define the research agenda that will exactly address those targeted solutions with positive impacts. The following actions emerge as high-priority and achievable in the near future: new research tools to study food systems; dis-aggregated intra-household surveys to reveal within-family inequalities in food access; increased scientific consensus on climate change impacts in sub-Saharan Africa; rapid response measures to address sudden emergencies, such as capturing excess rainfall water; financial tools to enable rapid responses with recovery measures afterwards; consideration of restrictions that excess heat and humidity impose on human productivity; secure land ownership and tenure rights to encourage long-term agricultural investment; mechanization at all stages along the food system; improved human capacity to innovate; encouragement for farms able to become more commercial, with support for those not (yet) able to transition; balanced mixed plant and animal diets to address nutrition, with more research on vegetables and fruits to improve human health; facilitation for somewhat larger medium-size farms that produce more efficiently; temporary safety nets for those transitioning out of agriculture; sustainable intensification focused where there is lowest risk of biodiversity loss for greatest production gain; encouragement for private sector to create more food system jobs in rural areas, especially for youth; research on soil biota that facilitate availability of nutrients such as phosphorus or benefit crop growth; attention on root systems; reconsideration of transgenic, hybrid and gene-editing approaches to crop improvement; increased use of the rich genetic diversity in crop and animal wild relatives and landraces in breeding programs.

I. Introduction

Food security, which encompasses food availability, access, utilization and stability (Van den Broeck & Maertens, 2016; Frels et al., 2019), is a key element in Sustainable Development Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture. We set out to identify actions that would enable full food security that are both high-priority and achievable within the next 2–10 years, coinciding with the SDG target of 2030. Our focus is on agriculture in the developing world, where food security is most needed. Our approach is to identify the most important drivers of food systems and then to look at ongoing processes in these food systems in search of achievable goals with a high return. In so doing, we present a big-picture overview of the current status for each area and then offer some recommendations, based on a much wider review that draws also on the authors' long combined experience working in these areas in public-sector agricultural research and development for the developing world.

A crucial point is to recognize that we are dealing with a complex, multi-faceted set of problems. Food systems include soil, water, air, crops, livestock, fish, natural vegetation, pollinators, soil-borne organisms, environmental sustainability, dietary sustainability, food security, food distribution, food demand, consumption, waste, livelihoods, justice and stakeholders from farmers to consumers; such complexity requires interdisciplinary, transdisciplinary and systems thinking (Dawson et al., 2019).

II. Major Drivers

a) *Population growth*

Norman E. Borlaug, awarded the Nobel Peace Prize 50 years ago for the plant breeding work that ushered in the Green Revolution, emphasized the "population monster". He noted that humankind "is not yet using adequately his potential for decreasing the rate of human reproduction" (Borlaug, 1972).

Nevertheless, global population growth has slowed considerably, to 2.3 births per woman. In almost half of the world's roughly 200 countries, mostly in Asia, Europe and North America, fertility rates have dropped below the replacement rate of 2.1 births per woman. However, in the least developed countries, covering more than 1 billion people, average birth rate is 4.1 per woman, with an average household size of 5. In Africa, the fertility rate is 4.4 births per woman. Death rates too are dropping, although not as fast as birth rates, so that for 25 countries around the world population size will still double between now and 2050 (Population Reference Bureau, 2020). About 90% of global population growth will occur in Africa and Asia. Many of those people–80%–will be in medium-sized cities of fewer than 500,000 inhabitants (Hazell, 2018).

b) *Climate change*

Agriculture occupies 40% of all global land area (Clapp, Newell, & Brent, 2018). Technological innovation in agri-food systems will have to accelerate in order to mitigate and adapt to climate change (IPCC, 2018). With

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climate change, dry regions will become drier, and wet regions wetter (Ruane & Rosenzweig, 2018). Predictions of extreme temperature point in one direction: more frequent heat. Heat extremes will hasten decomposition of soil organic matter (SOM) and decrease soil water availability, requiring crop irrigation with waste water or sewage and resulting in soil pollution (Fayiga & Saha, 2017). The effects on crop species will differ. As is well known, C3 plants are more vulnerable to elevated temperature and CO_2 levels than C4 plants (Lamboll, Stathers, & Morton, 2017). Damage due to crop diseases, pests and weeds extending their range under climate change is already vast, although to some extent predictable based on their presently known environmental adaptation (Hertel & de Lima, 2020). Other impacts on crop physiology, such as pollen maturation and survival, are complex. The agriculture and food sectors are not only victims of climate change but, according to most estimates, are also themselves responsible for about 25% of all greenhouse gas (GHG) emissions, complicating mitigation and adaptation in agriculture considerably (Clapp et al., 2018; Ruane & Rosenzweig, 2018).

Extreme rainfall events will include both lack and excess of precipitation, and be less predictable. Inland flooding and associated water logging of crops are expected, for example in East Africa (Lamboll, Stathers, & Morton, 2017; Ruane & Rosenzweig, 2018). Water logging leaches nutrients from the soil, resulting in negative nutrient imbalances on farmland and downstream (Fayiga & Saha, 2017). Sea-level has risen 20 cm from 1900 to 2020, faster than at any time in the past 2000 years (Lamboll, Stathers, & Morton, 2017). Sea level rises will increase coastal soil salinity levels, reducing crop yields (Fayiga & Saha, 2017; IPCC, 2018). Snow-fed river systems will receive less water, as less snow will fall in their watersheds (Ruane & Rosenzweig, 2018). By 2040, major productive, arable lands will find groundwater depleted or unreachable, with 28% of all cropland under high water stress, (Van der Elst & Williams, 2018). While most studies of agriculture and climate change focus on temperature and precipitation, a 30-year study in China indicates that other weather-related factors may also have large effects; for example, increased wind speed results in lower rice, wheat and maize yields, but increased humidity enhanced crop development (Zhang, Zhang, & Chen, 2017).

Fish stocks in tropical areas may decrease by up to 40% in 2050 compared to 2000, as a result of many factors ultimately linked to climate change (IPCC, 2018; Lam et al., 2020). African countries are most vulnerable to fisheries-related food insecurity although some may be able to compensate with aquaculture (Ding, Chen, Hilborn, & Chen, 2017).

Most models predict that lower latitudes, where most developing countries are located, will experience more severe changes and fluctuations in climate than higher latitudes (Ruane & Rosenzweig, 2018). Many developing countries, especially in Africa, are highly exposed and vulnerable, and with low adaptive capacity compared to developed countries (Sarkodie & Strezov, 2019). In addition, while climate predictions for many regions are in agreement, those for sub-Saharan Africa (SSA) are surprisingly unclear. Different analyses arrive at distinct, even sometimes opposing, conclusions about changes in temperature and precipitation, and even the frequent conclusion that the Horn of Africa and East Africa will see an increase in precipitation is not uniformly agreed upon (Serdeczny et al., 2017).

Climate change will disproportionately hit remote, marginalized semi-arid lands, which already experience scarce, unreliable rainfall and often have degraded soils. Populations there rely on rain fed agriculture, mixed crop and livestock farming or pastoralism, with restricted access to markets, infrastructure and services (Gannon, Crick, Rouhaud, Conway, & Fankhauser, 2018).

Crucially, the impact of relatively small absolute changes varies considerably according to the relative status of different sectors of the population, an effect masked by high-level aggregated approaches to modeling. (Hallegatte & Rozenberg, 2017), for example, show that although the poorest quintile of the population represents only a few percent of total GDP, much of their work is in the informal sector so that impacts will barely be reflected in GDP. Precarious living conditions add to vulnerability to extreme weather events, while rising food prices have a disproportionately large effect when total household income is low. Women in developing countries will be particularly affected, as they often work in the most marginalized activities with restricted access to resources. This is especially true in Africa, but also a factor in Asia (Gannon, Crick, Rouhaud, Conway, & Fankhauser, 2018; Chanana-Nag & Aggarwal, 2020). Many work on land owned by others for a wage, often less than that of men, with increased exposure to higher financial risk and instability.

Livestock, as the rest of agriculture, contributes to climate change – 14.5% of global GHG emissions – and will be negatively affected, resulting in increased competition for water and feed, and reduced production of milk, meat and eggs (Rojas-Downing, Nejadhashemi, Harrigan, & Woznicki, 2017; IPCC, 2018). Ruminant livestock are the greatest source of methane (Reay, Smith, Christensen, James, & Clark, 2018), while manure and fertilizer use in feed production account for almost half the GHG production in livestock management (Rojas-Downing et al., 2017).

As a result of the complexities of food systems, supposedly climate-smart policies could exacerbate rather than mitigate the challenges. Hasegawa et al., (2018) show that carbon taxes on GHG emissions would increase food prices, by increasing the costs of crop production, and demand for biofuel leads to elevated

land rents. This mitigation approach resulted in extra risk of hunger over no mitigation and a larger negative impact than climate change itself. The negative effects are more severe on livestock than on food crop prices, especially in low-income regions in SSA and South Asia. The authors stress that they do not argue against climate change mitigation or adaptation measures, but emphasize that study of trade-offs and the implementation of corrective measures on prices, and hence food security, is also important (Hasegawa et al., 2018).

The impact of climate change on labor is likely to be high. Capacity for work by people laboring outside in the sun is known to suffer, especially when humidity is high, as in agriculture and construction. Draft animals are likely to have similar declines in productivity as temperatures rise. And yet, these effects of climate change on agricultural labor productivity in many low-income countries are rarely taken into consideration, while already part of legislature in industrialized countries (Hertel & de Lima, 2020).

In order to address sudden challenges, one of the fundamental requirements is the capacity to innovate. This ability can be learned and upgraded (Leeuwis et al., 2014), indicating a need for capacity building not just in specific disciplines such as agronomy, but in developing the ability, willingness and confidence to successfully experiment with new approaches at short time intervals, thus creating resilience by systems thinking. With increased capacity to innovate, farmers are better prepared to respond, moving from "teaching a person how to fish" to "experimenting oneself on how to fish even better".

c) Recommendations for Climate Change

A very high priority must be for scientists to combine their efforts in a focus on sub-Saharan Africa. Absolute numbers and relative rates of poverty are very high, and most food production is reliant on rainfed agriculture. However, consensus on the impact of climate change is not high. It is urgent that more reliable predictions be produced quickly, to guide other research.

Raising preparedness to cope with and recover from sudden extreme weather events must be a priority. A set of scenarios for a range of events at different scales will indicate levels of resilience and specific areas in which resilience can be improved. For example, prepare to direct run-off of large amounts of rainfall water to storage facilities from where it later can easily be extracted.

Data from the poorest segments of society are absent from most aggregate assessments of the impacts of climate change. Disaggregated, large-scale household surveys are needed to ensure that impacts on these, which are likely to be most severe, can inform higher-level analyses.

Extreme weather events are likely to find expression in greater fluctuation in agricultural production that will affect farmers, consumers and the economy as a whole. New financial tools will be needed that can inject support very quickly when needed, reaping returns in agricultural boom years, when prices are generally lower.

The social costs of climate change on human productivity need to be better understood so that appropriate adaptation measures can be put in place.

d) Decline in research and development budgets

Cuts in agricultural research and development (R&D) budgets by high-income, public, mostly government budgets are increasingly common (Frels et al., 2019), as support is demanded elsewhere. Cutting R&D budgets in any sector sooner or later will result in fewer innovations that are able to address existing and new problems. In the developed world the private sector increasingly pays for much of agricultural R&D, often behind securely patented walls. In the developing world the low return on investment is a drag on private-sector agricultural R&D. In addition, "agricultural research is slow magic," with many of its returns accruing only after decades (Alston et al., 2020).

The importance of agricultural R&D is especially pronounced in developing countries, where increases in agricultural productivity reduced poverty more than productivity gains in industry or services (Ivanic & Martin, 2018). In those countries, public R&D remains crucial. The UN and the African Union Commission recommend that developing countries invest 1% of GDP in agricultural research, but in 2016 the vast majority of these countries reached at most only 0.3% of GDP (Beintema, Pratt, & Stads, 2020). R&D should not just aim to increase calories from a few staple crops, but also nutrients from other food groups, including fruits, vegetables, meat, eggs, and milk (Pingali & Aiyar, 2018; Hertel & de Lima, 2020).

Overseas Development Aid (ODA) provided an average of $11 billion per year for agricultural development between 1975 and 2013. ODA specifically for agricultural research grew from 2.9% to 7.7% of total ODA and was associated with high rates of return (Abler, 2017). Sub-Saharan Africa and South Asia were the major recipient regions. However, SSA consistently had the lowest score in development projects rated satisfactory by the World Bank. Abler (2017) attributes this to a lack of appreciation for SSA's diversity and complexity, lack of local human and infrastructure base to develop agriculture, and fruitless efforts to apply approaches that worked in Asia but are not suited for SSA. ODA investments in agriculture remain important, especially in SSA (Mason-D'Croz et al., 2019).

Reduced ODA inflows may also reflect positive developments, for example when a country exceeds donor limits on income per capita. For example, the

Organisation for Economic Co-operation and Development (OECD) sets a threshold of $12,000 per capita for three years consecutively (Calleja & Prizzon, 2019). Between 2004 and 2019, 35 low-income countries became middle-income countries (Jalles d'Orey & Prizzon, 2019) and the OECD expects an additional 29 countries to "graduate" before 2030 (Calleja & Prizzon, 2019). However, exceeding a threshold for mean per capita income does not guarantee that such countries will now themselves fund a healthy agricultural R&D sector. Furthermore, after transitioning to middle-income, countries receive outside investments as loans rather than grants. As a result, governments invest these loans in money-making sectors, such as infrastructure projects, rather than sectors such as agricultural R&D, under the impression that these latter sectors do not create financial returns in the short term (Engen and Prizzon, 2019). However, a meta-analysis of 492 studies showed that present-day return on investment in agricultural R&D continues to be high, above 50% per year (Rao, Hurley, & Pardey, 2019). At the same time many of the poorest countries stagnate in agricultural production and R&D, while their economic dependency on agriculture continues (Alston and Pardey, 2017).

Another relatively new and positive development is that medium-income countries, such as Brazil, China and India, increasingly define their own agricultural R&D agenda and are responsible for significant technology innovations for the developing world and beyond. While in high-income countries agricultural scientific publications doubled between 1996 and 2016, in newly middle-income countries a 4-to 30-fold increase was reported (Heisey & Fuglie, 2018). The growing role in agricultural R&D of these newly medium-income countries is not restricted to their government sector, but also their emergent private sector. As their success grows, these are likely to spread their influence regionally and even globally. For example, Seed Co, one of the largest homegrown private seed sector companies in SSA, was founded in Zimbabwe and now operates in more than 20 African countries.

e) Recommendation on R&D budgets

As low-income countries reduce investments in agricultural R&D, despite high internal rates of return on agricultural development, we advise governments to create incentives for private sector investment in agri-food systems. One approach might be lower taxes on such investments, especially in rural areas.

III. High-Priority and Achievable Goals

a) Restore resource-base degradation

Land degradation–measurable loss of the "biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands…arising from human activities and habitation patterns" (Barbier & Hochard, 2018)–now affects 25% of all global land, more than 90% of which is in developing countries (Barbier & Hochard, 2018; Tittonell, 2018). Increasing the amount of agriculture through changes in land use is increasingly difficult, even in Africa, where the arable land limit has already been reached in 45 of the 54 African countries and 65% of the land has degraded through unsustainable intensification (Kwame Yeboah, Jayne, Muyanga, & Chamberlin, 2019). Where expansion of agricultural land is still possible, it will be largely into low productivity land, resulting in further land degradation (Barbier & Hochard, 2018). This challenges Sustainable Development Goal 15, land degradation neutrality, defined as "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems" (UNCCD, 2016).

Innovations that increase returns to land and labor can motivate farmers to engage in more sustainable food systems, mitigating land degradation and thus further increasing returns. In addition, rural infrastructure and education have been shown to contribute most to increasing productivity for people on degraded land (Barbier & Hochard, 2018). Restoring their soils requires the mitigation of degrading factors, introducing biomass and nutrients, and producing new biomass from rotationally synergistic plants that are partially sequestered in the soil to increase soil organic matter (Tittonell, 2018). Depleted soils with reduced SOM and greater acidity may no longer respond to inorganic fertilizer, preventing new crop varieties delivering their potential yield (Kwame Yeboah, Jayne, Muyanga, & Chamberlin, 2019).

The provision of phosphate is particularly urgent. Phosphate fertilizer precipitates into complexes and becomes fixed in soils, with 75–90% becoming inaccessible to plants. As a result, phosphate is the second most applied fertilizer after nitrogen (Aloo, Makumba, & Mbega, 2020). Unlike nitrogen, however, rock phosphate is a finite resource, expected to be depleted in the next 100 to 500 years (Cottrell et al., 2018; Aloo et al., 2020). Methods are needed to allow plants to access the phosphorus tied up in soils. Some rhizobacteria can solubilize and liberate phosphorus from soil complexes and make it available to plants, and while they have been commercially available for about 15 years, the mechanisms of action are often unknown (Aloo et al., 2020). Other soil-borne organisms and micro-organisms can potentially restore degraded soils and have been little studied in that context. New methods allow the study of root systems in natural conditions (e.g., (El Hassouni et al., 2018)), enabling a better understanding of the hidden half of crop plants.

Organic farming has been proposed as a sustainable agri-food system that conserves

biodiversity, improves soil health and reduces GHG emission, with lower inputs and higher prices as potential incentives for producers, at least in more developed countries. While there remains considerable discussion on both yields and environmental benefits (Jouzi et al., 2017), an extensive literature review indicates that per unit output, organic farming is more polluting than conventional farming because of its lower average productivity for crops and livestock (Meemken & Qaim, 2018). Only 11% of the land devoted to organic systems is currently in Africa and Asia, and more than 80% of purchases take place in Europe and North America (Anderberg, 2020). We conclude that while organic agriculture may make a small contribution to food security in very special circumstances, it does not seem suited for developing country households, and certainly not in the next 2–10 years.

b) Recommendations on degraded resources

The study of micro-organisms that can make bound phosphorus available to plants is urgently needed, along with greater research into the role of other soil biota in promoting plant health.

The study of roots to enhance their role in yield and yield stability can be hugely expanded, with new approaches available to efficiently phenotype, genetically define and improve root systems in natural cropping conditions.

The treatment of crop seeds with microbial solutions deserves further research, as a way to promote their ability to restore degraded lands. The use of microbial solutions has a checkered history that spans centuries, but is now beginning to gain a measure of scientific respect. A better understanding of the mechanisms involved, which might include stimulating the development of the root system, could unlock the potential of microbial solutions to sustainably raise crop yields.

Policies that offer access to land and secure tenancy rights will be essential to encourage youth to make long-term investments in agriculture and sustainable intensification.

c) Reversing biodiversity loss

Dynamic changes in biodiversity are part of the planet's past and present evolution, with new species continuously arising and others declining, hitherto with little impact on humans. More recently, agriculture, and especially changes in land use, have been identified as major drivers of biodiversity loss (Tilman et al., 2017; Almond, Grooten, & Petersen, 2020)}.

To reach global food security by 2030, expansion of croplands and intensification of farming are options additional to crop yield increases, but both risk biodiversity loss by way of loss and fragmentation of natural habitat and adverse water and soil management. Trade-offs are inevitable. Globally, the negative effects of expansion have been worse than those of intensification (Kehoe et al., 2017). Integrated modeling of agro-ecological and economic factors indicate that biodiversity was most severely affected in the tropics (Zabel et al., 2019), with cropland expansion most critical, relative to intensification, in Central and South America and Central Africa, and intensification most important in SSA, India and China (Kehoe et al., 2017; Zabel et al., 2019).

Even when sustainable intensification is deemed preferable to cropland expansion, which involves habitat conversion, biodiversity within agricultural landscapes is threatened (Egli, Meyer, Scherber, Kreft, & Tscharntke, 2018). Increased production through intensification should be focused on those areas where yield gaps are relatively high but risks to biodiversity are relatively low. According to Egli et al., (2018), spatial land-use optimization scenarios can help to avoid 88% of projected biodiversity losses, reconciling trade-offs.

Despite a general trend towards reduced biodiversity in farming systems, over time and in terms of on-farm genetic diversity, mixed and relay cropping are still widely practiced, especially on smallholdings in the developing world. Considering yields from all such crops in a farm by area and by time can show total harvest increases. Mixtures of several crop species and of genetic diversity within a crop have been shown to reduce losses to pests and diseases. Mixtures may also contain species that provide beneficial or synergistic complementary services, which in combination can result in ecosystem productivity and stability and thus increased product yields, quality and profitability insurance for risk-averse farmers (Baumgärtner, 2007). Such services include penetrating soil pans, soil regeneration, increasing water infiltration, preventing excess water evaporation and improving water retention, offering shade, providing protection against wind and habitats for natural enemies and biocontrol agents, greater carbon sequestration, enhanced nitrogen fixation, and greater ability to cope with disturbance. Urban agriculture and home gardens with mixed systems, due to their small scale and personal inputs, can promote production of many traditional, non-staple niche and "orphan" crops that address specific tastes and needs, and hence contribute to biodiversity (Taylor & Lovell, 2014).

d) Recommendations on reversing biodiversity loss

There is an urgent need now to protect and encourage biodiversity that serves both humankind and the planet's resource base. Focusing intensification of production only there where the expected productivity gain is largest and potential biodiversity loss is smallest can facilitate that.

Crop wild relatives, landraces, and neglected and underutilized crops, representing biodiversity,

should be used more in modern crop breeding. (See Innovation in crops and animals, below).

e) Facilitating market access

Infrastructure constraints, such as a lack of roads to markets and longer-term (cooled) storage continue to restrict opportunities to earn income from excess crop production in much of the developing world. Investments in transport infrastructure have particularly lagged, despite being the largest portion in many infrastructure budgets, as the start from a low base (Gurara et al., 2017). Food transport and marketing will be sectors particularly affected when extreme rainfall leads to widespread flooding, which will particularly impact high-density cities (Vajjarapu, Verma, & Gulzar, 2019). In addition, an excess of intervening "middlemen" reduces the benefits that flow back to the original crop producers.

Traditionally, smallholder farmers sell excess production to passing traders or at the local market (Ferreira, Goh, & Valavi, 2017). In the past ten years, ODA has started to fund projects that explore digital mobile technologies to provide farmers with broader marketing channels (Ferreira, Goh, & Valavi, 2017; Qiang, Kuek, Dymond, & Esselaar, 2012). While mobile technologies are a promising area for farmers (and for providers of digital technology), regulations are needed and farmers may benefit from uniting in common groups to increase negotiation power with e-intermediaries, because beyond a minimum level of access, market power is more important than market access (Ferreira, Goh, & Valavi, 2017). Despite a checkered history, especially in Africa, producer organizations can facilitate access to input and output markets (Shiferaw, Hellin, & Muricho, 2016). There is some indication that membership of producer organizations is most popular with the middle class of farmers, with very low-income and high-income farmers choosing not to join. Key to future success for producer organizations is to take an expressed agribusiness orientation with strict business principles (Shiferaw, Hellin, & Muricho, 2011).

Despite some positive developments in agricultural production, Africa's food imports have quadrupled in the past two decades. However, countries differ considerably, providing opportunities for cross-border trade in Africa, which also creates salaried jobs for surplus labor. Hence, investment in the production of local staple crops, to offset growing imports, closely followed by mixed crop-livestock food systems, remains a priority, along with diversification and with an eye to potential exports (Christiaensen & Vandercasteelen, 2019). Since 2000, donors and funders increasingly support value chain development approaches with multiple stakeholders, aimed at food security, poverty reduction and gender equity (Donovan, Stoian, & Hellin, 2020).

In a study of 235 Regional Trade Agreements (RTA) involving 45 developing country exporters from among the countries most active in international trade, and 60 export destinations, north-north agreements were the majority until 1991. However, during 1991–2015, 86% of the RTAs involved north-south and south-south product movements. On average, developing countries clearly benefitted from RTAs, but while Asia doubled its share of world trade to 36%, Africa stagnated at 2–3% (Stender, 2019).

An increase in open international trade would create new opportunities for agricultural goods from developing countries. During much of the previous century, border restrictions limited global trade of food products. At the end of the 20th century globalization bloomed, but the 2008 financial crisis interrupted this expansion (Frels et al., 2019). Nevertheless, since 2000 exports of horticultural products have tripled in Latin America and quadrupled in Africa and Asia (Van den Broeck & Maertens, 2016). Horticulture products represent the single largest category of agri-food exports, making up 24–33% of all agri-food exports from Africa, developing Asia and Latin America. Horticulture diversifies exports and increases food security, because its value chain is very labor-intensive but at a relatively low skill level, thus providing an income for many, including women and youth in food processing, while at the same time the products represent high-value exports (Van den Broeck & Maertens, 2016). Opening up trade will not only increase food diversity, quality and safety, but also raise national income, thus contributing to food availability, access, utilization and market stability (Frels et al., 2019).

There does not appear to be any trade-off between horticulture production for export and domestic food production; both actually increase. Increased household income enables improved access to food, especially for contract farmers, but less significantly so for wage workers, although in the latter case female workers appear to benefit most (Van den Broeck & Maertens, 2016)

Increased export to the developed world requires food safety regulations and sanitary and phytosanitary measures of importing countries to be implemented. Faour-Klingbeil and Todd (2018) studied the West Asia and North Africa (WANA) region and noted that Morocco, Tunisia, Egypt and Jordan adapted their food safety regulations and saw their food exports grow over the long-term. Most countries in WANA were not able to reach international standards, because of low safety standards on-farm and in local markets, and a lack of scientific knowledge and political will. As the value chain upgrades to higher quality markets and upscales export options, food standards and certification become more stringent, with the result that agribusiness increasingly tends to focus on a limited

number of large and medium farms, rather than on many smallholdings (Qaim, 2017).

The inclusion of non-farm income sources by farming families when discussing agri-food systems is a dramatic transition from the past, and it requires recognition. Production systems diversify, diets diversify, livelihoods diversify and income sources diversify. Levels of analysis change too, from on-farm analyses, to farming systems analyses, to post farm gate analysis, to value chain analyses, and now to total agri-food systems analyses. This kind of straddling research should be included in future research agendas for them to remain relevant in changing times.

f) Recommendation for market access

We recommend that governments encourage a transition to commercial farming, which offers stronger routes to market access, improves food security, and provides employment and income for a diversified workforce, including women and youth. Those farms not yet able to transition may need other forms of facilitation and support.

g) Diversification of crops and diets

In the past 10–15 years, attention has begun to shift from the need to feed the hungry in developing countries, to the need to nourish those with insufficient access to nutritious food. More than two billion individuals are undernourished or malnourished, including those with stunting, wasting, vitamin and mineral deficiencies, anemia and obesity (Haddad et al., 2016).

In low-income, low-yielding subsistence farming, in the absence of trade and markets, families eat largely what their farm produces. Their dietary and nutritional adequacy is determined by what they grow. In true subsistence farming, increased diversity in home-grown crop production directly leads to increased diversity in nutrient intake and better health. But many of even the smallest farmers do purchase some food, thus somewhat diversifying their diets (Sibhatu & Qaim, 2018; Mehraban & Ickowitz, 2021). As farming initially intensifies, cropping diversity itself often decreases because the focus moves to the few most profitable major staples; as a result, diet diversity may decrease (Ickowitz, Powell, Rowland, Jones, & Sunderland, 2019; Mehraban & Ickowitz, 2021). Then, as farming further intensifies and commercializes, incomes rise, poverty falls, global connectedness grows, and information on nutrition, health and new taste experiences becomes available, interest in more diverse diets rises, as seen in newly medium-income countries (Pingali & Aiyar, 2018; Mehraban & Ickowitz, 2021). With rising incomes and standards of living, growth of the middle class and urbanization, there is an increased taste and demand for diversified diets, which progressively include animal-based foods, fruits and vegetables, and processed foods (Rojas-Downing et al., 2017; Allen, Heinrigs, & Heo, 2018; Van der Elst & Williams, 2018; Adesogan, Havelaar, McKune, Eilittä, & Dahl, 2020; Mehraban & Ickowitz, 2021).Overall, both on-farm diversification (within limits) and market access diversification can lead to fairly well diversified and healthy diets (Sibhatu, Krishna, & Qaim, 2015).

Cereals dominate many diets in the developing world as food staples, and have benefitted from a century of science-based crop improvement, as have staple root and tuber crops and several legume food crops. Most climate change research has focused on the major staples, wheat, rice, maize and soybean, but non-staple crops will be increasingly important in providing protein and micro-nutrients (Hertel & de Lima, 2020). Research on fruits and vegetables has lagged, and given the high nutritional value of many fruits and vegetables and the relatively low research base in many cases, very significant gains in nutritional food security can be expected when modern scientific improvement tools are applied. Furthermore, an entire class of edible plants has been labelled neglected and underutilized species (Padulosi et al., 2018). These NUS crops are often extremely rich in important micronutrients. Researchers have reduced the neglect to some extent, and consumers are being encouraged to use them more frequently and more widely, with large potential impacts on nutritional security particularly in developing countries, where NUS are often well adapted to low-input systems (Hunter et al., 2019; Siddique, Li, & Gruber, 2021)}.

Animal-source food (including milk and dairy products, meat, fish, and eggs) is a hotly discussed topic, with some noting that for the poor it provides crucial nutrients, while others point to its negative environmental impacts (Willett et al., 2019; Adesogan et al., 2020). The SDGs specifically refer to the importance of domesticated animal and fish production (UN General Assembly, 2015), in part because in diets with an excess of cereals the lack of micronutrients (e.g., bio-available vitamin A, vitamin D3, iron, iodine, zinc, calcium, folic acid) may lead to stunting in children and impaired cognitive development. Animal-based foods also provide high-quality proteins and essential fatty acids and may also enhance absorption of nutrients such as iron and vitamin A from plant-based food eaten at the same time. Animal-source foods contain the only natural source of vitamin B12; the lack of which may result in developmental disorders, anemia, and poor motor and cognitive functions. Micronutrient supplements may help to correct this, but are not an available option for many low-income households (Pingali & Sunder, 2017). Some animals also give traction power and all provide manure, both essential in low-income households. In developing countries, animals barely compete with humans for plant food, as animal feed contains only 14% products that humans

could also consume. Most animal feed comes from pastures and crop residues (Adesogan et al., 2020).

In this debate on nutrition and balanced diets it is important to avoid becoming unrealistically restrictive in prescribing what others should eat. There may be a need to look beyond country-wide, highly aggregated mean figures, because meal content is largely chosen by individuals, driven at the time by their own appetite and taste as well as access, availability and affordability. At the same time, social norms may mean that women and girls are malnourished even though the household appears to have adequate food quantity and quality (Pingali & Sunder, 2017). Innumerable combinations of food products can constitute a balanced meal. There should also be space in the debate for allowing for that kind of self-determining diversity.

h) Recommendations on diet and nutrition

Diversifying farm production should be a priority focus, moving towards commercial models with good market access. These farms can sell healthy food locally and regionally, while high-quality products are placed on national and international markets. Such products would include fruits, vegetables, livestock and aquatic foods.

Treatment of malnutrition, especially of hidden hunger, should shift to diversified, complementary plant and animal diets, possibly including biofortified crops, rather than direct micronutrient supplementation.

Research is needed on fruits and vegetables at a scale comparable with past investment in starchy staples, to increase production, transportability, shelf life and nutritional value, among others. Progress from the existing low research base is expected to be rapid.

Information about within-household inequity should be gathered as a priority, in order to inform the kinds of gender-transformational changes in social norms and high-level policies that will improve the access of women and girls to more nutritious diets.

i) Innovation in crops and animals

Innovations in crop improvement are not always actually that new, but their adoption on-farm has lagged, and not just in the developing world. Hybrid crop solutions have been applied in cross-pollinating crops, such as maize, for 100 years in both the developed and developing world. But hybrids and hybrid-enabled approaches in self-pollinating crops, harvesting hybrid vigor, remain far behind, while 10–15% yield boosts on top of conventional increases are possible by capturing the additive gene action component underpinning hybrid vigor (van Ginkel & Ortiz, 2018). Transgenic approaches have been widely adopted in many countries, although some, such as the EU members, continue to oppose them. Gene editing with CRISPR-Cas9 is proving very promising in a rapidly increasing range of organisms, including crops and livestock, although it too is currently blocked in the EU. We hope that all three approaches will be more widely adopted, with expected large yield and nutrition gains for each. Governments that set an example by enthusiastically promoting GM food crops, as the Bangladesh government did when it approved a GM eggplant variety with insect resistance for release to its farmers in 2013 (Shelton et al., 2018), could also boost adoption of new technologies.

Wild relatives and landraces have been used in a limited way in scientific breeding over the past 100 years or more, but there is a new and growing appreciation that they often contain traits, such as resistance and tolerance to biotic and abiotic stresses, that are highly desirable in response to climate change. New technologies are making it easier to identify and incorporate these traits into advanced varieties, and the value of wild relatives and landraces should be experimented with in many more crops (Kilian et al., 2021). Increasing photosynthetic efficiency and conferring nitrogen-fixing ability on cereals are two approaches that have so far failed to deliver on their initial promises, but new technologies such as high-throughput phenotyping of wild relatives and landraces may change that record (Langridge, 2018)

j) Recommendations for crop and animal innovation

The positive potential of transgenic, hybrid and hybrid-enabled, and gene-edited crops to achieve food security should be reconsidered, taking food safety requirements fully into consideration.

New technologies should be tested for crop and animal breeding, including the use of wild relatives and landraces to introduce novel genetic diversity for traits underpinning yield, quality, tolerance to biotic and abiotic stresses, and other challenges that climate change may bring.

k) Sustainable intensification of agriculture

Sustainable intensification, encompassing the multiple dimensions of food systems, as a foundation for food security can be traced back at least to the "Borlaug Hypothesis", adding a sustainability requirement to agricultural production (Borlaug, 1994). Later formulations have expanded the idea of ecological intensification to improve agricultural systems (Tittonell, 2018), not least to limit land conversion under climate change as a primary mitigation approach (IPCC, 2018). In practical terms, sustainable intensification aims to obtain higher yields per unit area and time, while applying a sustainable use of (natural) resources.

Mechanization offers considerable advantage, especially to young girls and women, by reducing some the drudgery that prevents them exploring other opportunities. "Retiring the hoe to the museum" is an African Union initiative to promote mechanization among women farmers in Africa that captures this notion well. Mechanization, high and low tech, has made great strides in Asia, but has lagged badly in Africa (Christiaensen, Rutledge, & Taylor, 2021) for well-

understood reasons, including degraded soils that require rehabilitation before agriculture can be intensified (Pingali & Aiyar, 2018; Tittonell, 2018).

Sustainable intensification can deliver greater resource efficiency, including less labor and reduced environmental damage, at the same time as it brings global food security within reach (Saiz-Rubio & Rovira-Más, 2020). A low-hanging fruit would be to reduce post-harvest food losses. Globally, one third of food produced is lost; for staple cereals, which make up the bulk of the losses on a calorie basis, losses average 50–60% (Kumar & Kalita, 2017). Minimizing loss and waste translates directly into greater value, so we would expect the private sector to be interested in addressing loss and waste to maintain or improve their profits. The ongoing trend to larger farms and increasing commercialization, including participation in high-value export markets with strict food standards, will reduce losses earlier in the agri-food system chain.

The global average age of farmers, including those in developing countries, is presently around 60 years. These farmers represent high levels of accumulated knowledge based on years of field experience. For eager, young but less experienced farmers to take over, data-enhanced decision-making tools will enable them to be more effective in sustainably intensifying farming with approaches that are more knowledge- and skill-intensive (Saiz-Rubio & Rovira-Más, 2020). Dozens of farm management information systems are already commercially available to expedite multi-stage decision-making and interest is growing rapidly in such cash crop sectors as coffee production (Sott et al., 2020). While this type of farming has not reached food production in the developing world, we expect that once it is adopted by the cash crop sector there, it will spawn adaptations that are realistic for use also in food production.

An important drag on sustainable intensification is the small size of agricultural holdings, especially in developing countries (Hazell, 2018). These small farms may become even smaller as a result of inheritance customs and in rural Africa, as life expectancies increase, young people inherit land later in life, and holding size will be smaller than in past generations (Kwame Yeboah, Jayne, Muyanga, & Chamberlin, 2019). Consolidation into larger units may provide a solution, with productivity per unit area increasing once farms reach a critical size (Savastano & Scandizzo, 2017). Net value, efficiency and total factor productivity indicators increase with farm size (Garzón Delvaux, Riesgo, & Gomez y Paloma, 2020) due to mechanization and increased input use efficiency (Kwame Yeboah, Jayne, Muyanga, & Chamberlin, 2019). The notion that small farms produce more efficiently per hectare than larger farms, known as the inverse relationship (IR) between land area and output or productivity, is thus a limited interpretation when total factor productivity of integrated farming is taken into account (Savastano & Scandizzo, 2017; Kwame Yeboah, Jayne, Muyanga, & Chamberlin, 2019; Dourandish, Saghaian, Shahnoushi Forushani, Mohammadrezazadeh, & Kuhestani, 2020; Garzón Delvaux et al., 2020). While support for small farms seems well justified for social development reasons, for longer-term national development, poverty alleviation and food security somewhat larger, medium-sized farms should also be supported (Garzón Delvaux et al., 2020). The fashionable opinion among some consumers and opinion-makers in certain high-income countries, which favors regional, low-tech food from "small is beautiful" farms, would leave the poorest farmers in developing countries at high risk for food and nutrition insecurity (Qaim, 2017).

As urbanization grows, city dwellers influence food product choice and processing aspects, so that post-farm links in the food system value chain must adjust to changing demand. This transition to upgraded diets in cities could create new employment opportunities for youth, and result in some small farms being able to cater to these new urban needs, for example by providing specialty crops at higher prices (Hazell, 2018). At the same time, urban agriculture has seen increased interest, although most of the harvested food from urban agriculture is for self-consumption, with the remainder sold in the market (Armanda, Guinée, & Tukker, 2019). Some people also doubt whether the small harvests of urban agriculture will actually make a significant difference to food security (Specht, Schimichowski, & Fox-Kämper, 2021).

An important priority is for transdisciplinary, agro-ecological research into food systems to understand, model, predict and guide future farming systems from a multi-dimensional standpoint (van Ginkel et al., 2013; Pingali & Sunder, 2017; Niles et al., 2018; Ingram & Zurek, 2018). Biophysical, technological, processing, market, social, and policy environments and drivers are all involved (Ingram & Zurek, 2018). While the National Academies of Sciences, Engineering, and Medicine in the USA list "transdisciplinary science and systems approaches" as their first breakthrough and recommendation in their report "Science Breakthroughs to Advance Food and Agricultural Research by 2030" (National Academies of Sciences, Engineering, and Medicine, 2019), full acceptance of the benefits of adopting a systems approach has been lacking. Not only are systems-wide analyses essential, but most important now is to develop new transdisciplinary concepts, methods, tools and metrics to study such complex systems holistically (Ditzler et al., 2018).

l) Recommendations for sustainable intensification

Investment is needed into research and development on mechanization and labor-saving precision-agriculture equipment. Topics might include

local weather prediction, early warning systems for natural hazards, knowledge-intensive breeding, automated farming, product transport, food processing and consumer service, among others.

The education and training of eager young potential farmers must become a priority. It should focus on modern farming methods and enhance their personal capacity to experiment and innovate, resulting in a cadre of young people who are both more informed and more enthusiastic about modern farming.

Technology and policy research is needed to facilitate the transition from unviable small farms to larger holdings with a more commercial orientation. Policies will have to include safety nets for those transitioning out of agriculture, and there should also be improved opportunities for rural jobs and income.

Medium-sized towns and cities rather than mega-cities should receive the bulk of investment in areas such as sustainable intensification, rural diversification, and access to technology and infrastructure. The goal is to provide local employment that is intellectually challenging and financially rewarding in order to encourage youth to stay in those areas and contribute directly and indirectly to greater food security.

New transdisciplinary concepts, methods, tools and metrics need to be developed to enable the holistic study of complex, biophysical and socio-economic aspects of food systems.

IV. Conclusions

In our efforts to propose a research and development agenda for food systems in the near future, we follow the impact pathway backwards in order to avoid the trap of developing a science-based solution that is looking for a problem (van Ginkel et al., 2013). First, determine the food system-related needs and constraints of farmer and consumer families and the wider society, directly with these stakeholders. Then decide which biophysical and policy outcomes will positively address and satisfy those needs and constraints, and have impact. Having identified desirable outcomes, we then propose agriculture-related value chain and on-farm outputs that can result in those outcomes. Finally, the outputs we have identified determine the R&D needed to produce them, taking us back to the start of the impact pathway. If the process is rigorous, science-based, transdisciplinary and inclusive, following the impact pathway backwards near guarantees that R&D is precisely focused on the final target population, and will resolve the most urgent social issues.

Using this approach, we recommend the following actions and goals for the coming decade.

Entire integrated food systems require new tools to study systems holistically. Dis-aggregated intra-household surveys will indicate, down to the individual level, where food needs are most acute. We need better predictions of climate change impacts in SSA. Measures to harvest excess water during sudden rain events and retrieve it when needed are essential. Financial tools are needed that can inject funding rapidly to address sudden events, and later retrieve income when economies recover and grow. Better understanding of the effects of excess heat and humidity on human productivity will allow more complete planning and preparation. Secure land tenure rights and rental agreements will encourage long-term sustainable intensification and related investment, especially by rural youth. Mechanization is needed at all stages along the food system. Human capacity to innovate needs to be improved through education, which will also attract rural youth. Facilitation, for example through market access and infrastructure, is needed for farms to transition to commercial farming, which will also create jobs, while farms not (yet) able should receive support to enhance and stabilize production. Balanced plant and animal diets, including valuable neglected and underutilized species, should have priority in addressing nutritional needs. Diversification of farm production and food provision by research to improve vegetables and fruits will improve health and create jobs. Somewhat larger medium-size farms produce crops and food products more efficiently and should be encouraged by supporting related R&D and capacity development, along with temporary safety nets for those transitioning out of agriculture, with new job creation in rural areas. Intensification should focus on those lands that have the lowest potential of biodiversity loss, and the greatest potential gain in production. Facilitating the private sector to create more interesting jobs in rural areas, especially for youth, will also upgrade services to local communities. Investment in smaller rural towns and cities to bring modern food system technologies will provide new jobs. Research on soil biota will help to make nutrients available that are now tied up in the soil, such as phosphorus, while the positive effects of microbial solutions need a concerted effort to understand how they can benefit plant growth. Roots remain understudied, but with new breakthroughs need attention that could make rapid progress in optimizing plant development. Transgenic, hybrid and gene-editing approaches to crop improvement should be explored, where they can help reach food and nutrition security. Breeding new crop and animal types will benefit from the rich genetic diversity in their wild relatives and landraces, for which tools are becoming available.

Acknowledgement

We thank Jeremy Cherfas for help with preparing the paper for publication.

References Références Referencias

1. Abler, D. (2017). The International Role in Agricultural Development. in D. Blandford & K. Hassapoyannes (Eds.), Global Challenges for Future Food and Agricultural Policies World Scientific Series in Grand Public Policy Challenges of the 21st Century Volume 1 (pp. 39-60). World Scientific. doi:10.1142/9789813235403_0003
2. Adesogan, A. T., Havelaar, A. H., McKune, S. L., Eilittä, M., & Dahl, G. E. (2020). Animal source foods: Sustainability problem or malnutrition and sustainability solution? Perspective matters. Global Food Security, 25, 100325. https://doi.org/10.1016/j.gfs.2019.100325
3. Allen, T., Heinrigs, P., & Heo, I. (2018). Agriculture, Food and Jobs in West Africa. Paris: OECD Publishing. https://doi.org/10.1787/dc152bc0-en
4. Almond, R. E. A., Grooten, M., & Petersen, T. (Eds.). (2020). Living Planet Report 2020 - Bending the curve of biodiversity loss. Gland: WWF.
5. Aloo, B. N., Makumba, B. A., & Mbega, E. R. (2020). Phosphate-solubilizing rhizobacteria: Diversity, mechanisms, and prospects in sustainable agriculture. Preprints. Retrieved from https://www.preprints.org/manuscript/202009.0681
6. Alston, J. M., Pardey, P. G., & Rao, X. (2020). The Payoff to Investing in CGIAR Research. Arlington: SoAR Foundation. Retrieved from https://supportagresearch.org/assets/pdf/soar_cgiar_key_findings_final.pdf
7. Anderberg, S. (2020). The Contribution of Organic Agriculture to Poverty Reduction. in M. Breiling & V. Anbumozhi (Eds.), Vulnerability of Agricultural Production Networks and Global Food Value Chains Due to Natural Disasters (pp. 41-71). Jakarta: Economic Research Institute for ASEAN and East Asia.
8. Armanda, D. T., Guinée, J. B., & Tukker, A. (2019). The second green revolution: Innovative urban agriculture's contribution to food security and sustainability–a review. Global Food Security, 22, 13-24. https://doi.org/10.1016/j.gfs.2019.08.002
9. Barbier, E. B., & Hochard, J. P. (2018). Land degradation and poverty. Nature Sustainability, 1(11), 623-631. doi:10.1038/s41893-018-0155-4
10. Baumgärtner, S. (2007). The insurance value of biodiversity in the provision of ecosystem services. Natural Resource Modeling, 20, 87-127. doi:10.1111/j.1939-7445.2007.tb00202.x
11. Beintema, N., Pratt, A. N., & Stads, G.-J. (2020). Key Trends in Global Agricultural Research Investment. Washington, DC: International Food Policy Research Institute. Retrieved from https://www.asti.cgiar.org/sites/default/files/pdf/Global-update-ASTI-note.pdf
12. Borlaug, N. E. (1994). Agricultural research for sustainable development. Testimony of Dr. Norman Borlaug before the U.S. House of Representatives Committee on Agriculture, Subcommittee on Foreign Agriculture and Hunger March 1, 1994.
13. Borlaug, N. E. (1972). The Green Revolution. Peace and Humanity. Mexico City: CIMMYT.
14. Calleja, R., & Prizzon, A. (2019). Moving away from aid: Lessons from country studies. London: ODI. Retrieved from https://cdn.odi.org/media/documents/191128_summary_report_final_v1.pdf
15. Chanana-Nag, N., & Aggarwal, P. K. (2020). Woman in agriculture, and climate risks: Hotspots for development. Climatic Change, 158(1), 13-27. doi:10.1007/s10584-018-2233-z
16. Christiaensen, L. J., & Vandercasteelen, J. (2019). Earning more on the farm. In K. Beegle & L. J. Christiaensen (Eds.), Accelerating Poverty Reduction in Africa. Washington DC: World Bank.
17. Christiaensen, L., Rutledge, Z., & Taylor, J. E. (2021). Viewpoint: The future of work in agri-food. Food Policy, 99, 101963. https://doi.org/10.1016/j.foodpol.2020.101963
18. Clapp, J., Newell, P., & Brent, Z. W. (2018). The global political economy of climate change, agriculture and food systems. The Journal of Peasant Studies, 45(1), 80-88. doi:10.1080/03066150.2017.1381602
19. Cottrell, R. S., Fleming, A., Fulton, E. A., Nash, K. L., Watson, R. A., & Blanchard, J. L. (2018). Considering land–sea interactions and trade-offs for food and biodiversity. Global Change Biology, 24(2), 580-596. https://doi.org/10.1111/gcb.13873
20. Dawson, I. K., Park, S. E., Attwood, S. J., Jamnadass, R., Powell, W., Sunderland, T., & Carsan, S. (2019). Contributions of biodiversity to the sustainable intensification of food production. Global Food Security, 21, 23-37. https://doi.org/10.1016/j.gfs.2019.07.002
21. Ding, Q., Chen, X., Hilborn, R., & Chen, Y. (2017). Vulnerability to impacts of climate change on marine fisheries and food security. Marine Policy, 83, 55-61. https://doi.org/10.1016/j.marpol.2017.05.011
22. Ditzler, L., Klerkx, L., Chan-Dentoni, J., Posthumus, H., Krupnik, T. J., Ridaura, S. L., … Groot, J. C. J. (2018). Affordances of agricultural systems analysis tools: A review and framework to enhance tool design and implementation. Agricultural Systems, 164, 20-30. https://doi.org/10.1016/j.agsy.2018.03.006
23. Donovan, J., Stoian, D., & Hellin, J. (2020). Value chain development and the poor: Promise, delivery and opportunities for impact at scale. Rugby: Practical Action Publishing. doi:10.3362/9781788530576

24. Dourandish, A., Saghaian, S., Shahnoushi Forushani, N., Mohammadrezazadeh, N., & Kuhestani, S. (2020). The relation between property rights, farm size and technical efficiency for the developing countries' agricultural sector. Journal of International Development, 32(5), 749-762. https://doi.org/10.1002/jid.3476
25. Egli, L., Meyer, C., Scherber, C., Kreft, H., & Tscharntke, T. (2018). Winners and losers of national and global efforts to reconcile agricultural intensification and biodiversity conservation. Global Change Biology, 24(5), 2212-2228. https://doi.org/10.1111/gcb.14076
26. El Hassouni, K., Alahmad, S., Belkadi, B., Filali-Maltouf, A., Hickey, L. T., & Bassi, F. M. (2018). Root system architecture and its association with yield under different water regimes in durum wheat. Crop Science, 58(6), 2331-2346. https://doi.org/10.2135/cropsci2018.01.0076
27. Engen, L., & Prizzon, A. (2019). Exit from aid: An analysis of donor experiences. London: ODI. Retrieved from http://hdl.handle.net/10419/206743
28. Fayiga, O. A., & Saha, K. U. (2017). Effect of climate change on soil productivity in developing countries. Asian Journal of Environment & Ecology, 4(1), 1-22. Retrieved from doi: 10.9734/AJEE/2017/35485
29. Ferreira, K. J., Goh, J., & Valavi, E. (2017). Intermediation in the Supply of Agricultural Products in Developing Economies. Working Paper 18-033. Cambridge: Harvard Business School. Retrieved from https://www.hbs.edu/ris/Publication%20Files/18-033_8fcdda05-0410-4a43-b329-4e30d790cea b.pdf
30. Frels, K., Chopra, R., Dorn, M. K., Wyse, L. D., Marks, D. M., & Anderson, A. J. (2019). Genetic diversity of field pennycress (Thlaspi arvense) reveals untapped variability and paths toward selection for domestication. Agronomy, 9(6). doi:10.3390/agronomy9060302
31. Gannon, K. E., Crick, F., Rouhaud, E., Conway, D., & Fankhauser, S. (2018). Supporting private adaptation to climate change in semi-arid lands in developing countries. London: Grantham Research Institute on Climate Change and the Environment.
32. Garzón Delvaux, P. A., Riesgo, L., & Gomez y Paloma, S. (2020). Are small farms more performant than larger ones in developing countries. Science Advances, 6(41), eabb8235. doi:10.1126/sciadv.abb8235
33. Gurara, D., Klyuev, V., Mwase, N., Presbitero, A., Xin, C., Xu, G., & Bannister, G. (2017). Trends and challenges in infrastructure investment in low income developing countries. Strategy, policy, and review department IMF Working Paper WP/17/233.
34. Haddad, L., Hawkes, C., Waage, J., Webb, P., Godfray, C., & Toulmin, C. (2016). Food systems and diets: Facing the challenges of the 21st century. London: Global Panel on Agriculture and Food Systems for Nutrition. Retrieved from http://glopan.org/sites/default/files/ForesightReport.pdf
35. Hallegatte, S., & Rozenberg, J. (2017). Climate change through a poverty lens. Nature Climate Change, 7(4), 250-256. doi:10.1038/nclimate3253
36. Hasegawa, T., Fujimori, S., Havlík, P., Valin, H., Bodirsky, B. L., Doelman, J. C., … Witzke, P. (2018). Risk of increased food insecurity under stringent global climate change mitigation policy. Nature Climate Change, 8, 699-703. doi:10.1038/s41558-018-0230-x
37. Hazell, P. B. R. (2018). Urbanization, Agriculture, and Smallholder Farming. In R. Serraj & P. Pingali (Eds.), Agriculture & Food Systems to 2050 World Scientific Series in Grand Public Policy Challenges of the 21st Century (pp. 137-160). World Scientific. doi:10.1142/9789813278356_0004
38. Heisey, P. W., & Fuglie, K. O. (2018). Public agricultural R&D in high-income countries: Old and new roles in a new funding environment. Global Food Security, 17, 92-102. https://doi.org/10.1016/j.gfs.2018.03.008
39. Hertel, T. W., & de Lima, C. Z. (2020). Viewpoint: Climate impacts on agriculture: Searching for keys under the streetlight. Food Policy, 95, 101954. https://doi.org/10.1016/j.foodpol.2020.101954
40. Hunter, D., Borelli, T., Beltrame, D. M. O., Oliveira, C. N. S., Coradin, L., Wasike, V. W., … Tartanac, F. (2019). The potential of neglected and underutilized species for improving diets and nutrition. Planta, 250(3), 709-729. doi:10.1007/s00425-019-03169-4
41. Ickowitz, A., Powell, B., Rowland, D., Jones, A., & Sunderland, T. (2019). Agricultural intensification, dietary diversity, and markets in the global food security narrative. Global Food Security, 20, 9-16. https://doi.org/10.1016/j.gfs.2018.11.002
42. Ingram, J., & Zurek, M. (2018). Food Systems Approaches for the Future. In R. Serraj & P. Pingali (Eds.), Agriculture & Food Systems to 2050 World Scientific Series in Grand Public Policy Challenges of the 21st Century (pp. 547-567). World Scientific. doi:10.1142/9789813278356_0017
43. IPCC. (2018). Summary for Policymakers. In V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, … T. Waterfield (Eds.), Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of

climate change, sustainable development, and efforts to eradicate poverty.
44. Ivanic, M., & Martin, W. (2018). Sectoral productivity growth and poverty reduction: National and global impacts. World Development, 109, 429-439. https://doi.org/10.1016/j.worlddev.2017.07.004
45. Jalles d'Orey, M. A., & Prizzon, A. (2019). Exit from aid: An analysis of donor experiences. London: ODI. Retrieved from https://cdn.odi.org/media/documents/12661.pdf
46. Jouzi, Z., Azadi, H., Taheri, F., Zarafshani, K., Gebrehiwot, K., Van Passel, S., & Lebailly, P. (2017). Organic farming and small-scale farmers: Main opportunities and challenges. Ecological Economics, 132, 144-154. https://doi.org/10.1016/j.ecolecon.2016.10.016
47. Kehoe, L., Romero-Muñoz, A., Polaina, E., Estes, L., Kreft, H., & Kuemmerle, T. (2017). Biodiversity at risk under future cropland expansion and intensification. Nature Ecology and Evolution, 1. doi:10.1038/s41559-017-0234-3
48. Kilian, B., Dempewolf, H., Guarino, L., Werner, P., Coyne, C., & Warburton, M. L. (2021). Crop science special issue: Adapting agriculture to climate change: A walk on the wild side. Crop Science, 61(1), 32-36. https://doi.org/10.1002/csc2.20418
49. Kumar, D., & Kalita, P. (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods, 6(1), 8. doi:10.3390/foods6010008
50. Kwame Yeboah, F., Jayne, T. S., Muyanga, M., & Chamberlin, J. (2019). Youth access to land, migration and employment opportunities: evidence from sub-Saharan Africa. Rome: IFAD.
51. Lam, V. W. Y., Allison, E. H., Bell, J. D., Blythe, J., Cheung, W. W. L., Frölicher, T. L., … Sumaila, U. R. (2020). Climate change, tropical fisheries and prospects for sustainable development. Nature Reviews Earth & Environment, 1(9), 440-454. doi:10.1038/s43017-020-0071-9
52. Lamboll, R., Stathers, T., & Morton, J. (2017). Climate Change and Agricultural Systems. In S. Snapp & B. Pound (Eds.), Agricultural Systems: Agroecology and Rural Innovation for Development (pp. 441-490). San Diego: Academic Press. https://doi.org/10.1016/B978-0-12-802070-8.00013-x
53. Langridge, P. (2018). Innovation in Breeding and Biotechnology. In R. Serraj & P. Pingali (Eds.), Agriculture & Food Systems to 2050 World Scientific Series in Grand Public Policy Challenges of the 21st Century (pp. 245-284). World Scientific. doi:10.1142/9789813278356_0008
54. Leeuwis, C., Schut, M., Waters-Bayer, A., Mur, R., Atta-Krah, K., & Douthwaite, B. (2014). Capacity to innovate from a system CGIAR research program perspective. Penang: CGIAR Research Program on Aquatic Agricultural Systems. Retrieved from https://cgspace.cgiar.org/handle/10568/87913
55. Mason-D'Croz, D., Sulser, T. B., Wiebe, K., Rosegrant, M. W., Lowder, S. K., Nin-Pratt, A., … Robertson, R. D. (2019). Agricultural investments and hunger in Africa: Modeling potential contributions to SDG2–zero hunger. World Development, 116, 38-53. https://doi.org/10.1016/j.worlddev.2018.12.006
56. Meemken, E.-M., & Qaim, M. (2018). Organic agriculture, food security, and the environment. Annual Review of Resource Economics, 10(1), 39-63. doi:10.1146/annurev-resource-100517-023252
57. Mehraban, N., & Ickowitz, A. (2021). Dietary diversity of rural Indonesian households declines over time with agricultural production diversity even as incomes rise. Global Food Security, 28, 100502. doi:https://doi.org/10.1016/j.gfs.2021.100502
58. National Academies of Sciences, Engineering, and Medicine. (2019). Science Breakthroughs to Advance Food and Agricultural Research by 2030. Washington, DC: The National Academies Press. doi:10.17226/25059
59. Niles, M. T., Ahuja, R., Barker, T., Esquivel, J., Gutterman, S., Heller, M. C., … Vermeulen, S. (2018). Climate change mitigation beyond agriculture: A review of food system opportunities and implications. Renewable Agriculture and Food Systems, 33(3), 297-308. doi: 10.1017/S1742170518000029
60. Padulosi, S., Cawthorn, D.-M., Meldrum, G., Flore, R., Halloran, A., & Mattei, F. (2018). Leveraging Neglected and Underutilized Plant, Fungi, and Animal Species for More Nutrition Sensitive and Sustainable Food Systems. In P. Ferrante, E. Berry, & J. Anderson (Eds.), Encyclopedia of Food Security and Sustainability. Elsevier. doi:10.1016/B978-0-08-100596-5.21552-7
61. Pingali, P., & Aiyar, A. (2018). Food, Agriculture, and Nutrition Policy: Looking Ahead to 2050. In R. Serraj & P. Pingali (Eds.), Agriculture & Food Systems to 2050 World Scientific Series in Grand Public Policy Challenges of the 21st Century (pp. 609-653). World Scientific. doi:10.1142/9789813278356_0017
62. Pingali, P., & Sunder, N. (2017). Transitioning toward nutrition-sensitive food systems in developing countries. Annual Review of Resource Economics, 9(1), 439-459. doi:10.1146/annurev-resource-100516-053552
63. Population Reference Bureau. (2020). World Population Data Sheet. Retrieved 2021-03-24, from https://www.prb.org/2020-world-population-data-sheet/
64. Qaim, M. (2017). Globalisation of agrifood systems and sustainable nutrition. Proceedings of the

Nutrition Society, 76(1), 12-21. doi: 10.1017/S0029665116000598
65. Qiang, C., Kuek, S., Dymond, A., & Esselaar, S. (2012). Report No. 96226-GLB Mobile Applications for Agriculture and Rural Development. Washington DC: ICT Sector Unit, World Bank. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/21892/Mobile0applica0nd0rural0development.pdf
66. Rao, X., Hurley, T. M., & Pardey, P. G. (2019). Are agricultural R &D returns declining and development dependent? World Development, 122, 27-37. https://doi.org/10.1016/j.worlddev.2019.05.009
67. Reay, D. S., Smith, P., Christensen, T. R., James, R. H., & Clark, H. (2018). Methane and global environmental change. Annual Review of Environment and Resources, 43(1), 165-192. doi:10.1146/annurev-environ-102017-030154
68. Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management, 16, 145-163. https://doi.org/10.1016/j.crm.2017.02.001
69. Ruane, A. C., & Rosenzweig, C. (2018). Climate Change Impacts on Agriculture. In R. Serraj & P. Pingali (Eds.), Agriculture & Food Systems to 2050 World Scientific Series in Grand Public Policy Challenges of the 21st Century (pp. 161-191). World Scientific. doi:10.1142/9789813278356_0017
70. Saiz-Rubio, V., & Rovira-Más, F. (2020). From smart farming towards agriculture 5.0: A review on crop data management. Agronomy, 10(2). doi:10.3390/agronomy10020207
71. Sarkodie, S. A., & Strezov, V. (2019). Economic, social and governance adaptation readiness for mitigation of climate change vulnerability: Evidence from 192 countries. Science of the Total Environment, 656, 150-164. https://doi.org/10.1016/j.scitotenv.2018.11.349
72. Savastano, S., & Scandizzo, P. L. (2017). Revisiting the farm size–productivity relationship: New evidence from sub-Saharan African countries. In P. Pingali & G. Feder (Eds.), Agriculture and Rural Development in a Globalizing World: Challenges and Opportunities. Routledge. Retrieved from https://doi.org/10.4324/9781315314051
73. Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., … Reinhardt, J. (2017). Climate change impacts in sub-Saharan Africa: From physical changes to their social repercussions. Regional Environmental Change, 17(6), 1585-1600. doi:10.1007/s10113-015-0910-2
74. Shelton, A. M., Hossain, M. J., Paranjape, V., Azad, A. K., Rahman, M. L., Khan, A. S. M. M. R., … Mc Candless, L. (2018). Bt eggplant project in Bangladesh: History, present status, and future direction. Frontiers in Bioengineering and Biotechnology, 6, 106. doi:10.3389/fbioe.2018.00106
75. Shiferaw, B., Hellin, J., & Muricho, G. (2011). Improving market access and agricultural productivity growth in Africa: What role for producer organizations and collective action institutions. Food Security, 3(4), 475-489. doi:10.1007/s12571-011-0153-0
76. Shiferaw, B., Hellin, J., & Muricho, G. (2016). Markets Access and Agricultural Productivity Growth in Developing Countries: Challenges and Opportunities for Producer Organizations. In J. Bijman, R. Muradian, & J. Schuurman (Eds.), Cooperatives, Economic Democratization and Rural Development (pp. 103-124). Cheltenham: Edward Elgar Publishing. doi:10.4337/9781784719388.00013
77. Sibhatu, K. T., Krishna, V. V., & Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. Proceedings of the National Academy of Sciences USA, 112(34), 10657. doi:10.1073/pnas.1510982112
78. Sibhatu, K. T., & Qaim, M. (2018). Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. Food Policy, 77, 1-18. https://doi.org/10.1016/j.foodpol.2018.04.013
79. Siddique, K. H. M., Li, X., & Gruber, K. (2021). Rediscovering Asia's forgotten crops to fight chronic and hidden hunger. Nature Plants, 7(2), 116-122. doi:10.1038/s41477-021-00850-z
80. Sott, M. K., Furstenau, L. B., Kipper, L. M., Giraldo, F. D., López-Robles, J. R., Cobo, M. J., … Imran, M. A. (2020). Precision techniques and agriculture 4.0 technologies to promote sustainability in the coffee sector: State of the art, challenges and future trends. IEEE Access, 8, 149854-149867. doi:10.1109/ACCESS.2020.3016325
81. Specht, K., Schimichowski, J., & Fox-Kämper, R. (2021). Multifunctional Urban Landscapes: The Potential Role of Urban Agriculture as an Element of Sustainable Land Management. In T. Weith, T. Barkmann, N. Gaasch, S. Rogga, C. Strauß, & J. Zscheischler (Eds.), Sustainable Land Management in a European Context (pp. 291-303). Cham: Springer International Publishing. doi:10.1007/978-3-030-50841-8_15
82. Stender, F. (2019). Sign here, please! On developing countries' market access conditions in regional trade agreements. Review of Development Economics, 23(3), 1347-1367. https://doi.org/10.1111/rode.12591

83. Taylor, J. R., & Lovell, S. T. (2014). Urban home food gardens in the global north: Research traditions and future directions. Agriculture and Human Values, 31(2), 285-305. doi:10.1007/s10460-013-9475-1
84. Tilman, D., Clark, M., Williams, D. R., Kimmel, K., Polasky, S., & Packer, C. (2017). Future threats to biodiversity and pathways to their prevention. Nature, 546(7656), 73-81. doi:10.1038/nature22900
85. Tittonell, P. (2018). Ecological Intensification of Agriculture. In R. Serraj & P. Pingali (Eds.), Agriculture & Food Systems to 2050 World Scientific Series in Grand Public Policy Challenges of the 21st Century (pp. 437-472). World Scientific. doi:10.1142/9789813278356_0017
86. UN General Assembly. (2015). Transforming our world: the 2030 Agenda for Sustainable Development, A/RES/70/1. Retrieved from https://www.refworld.org/docid/57b6e3e44.html [accessed 30 March 2021]
87. UNCCD. (2016). Report of the Conference of the Parties on its twelfth session, held in Ankara from 12 to 23 October 2015. Part two: action taken. Bonn: United Nations Convention to Combat Desertification (UNCCD). Retrieved from https://www.unccd.int/official-documents/cop-12-ankara-2015/iccdcop1220add1
88. Vajjarapu, H., Verma, A., & Gulzar, S. (2019). Adaptation policy framework for climate change impacts on transportation sector in developing countries. Transportation in Developing Economies, 5(1), 3. doi:10.1007/s40890-019-0071-y
89. Van den Broeck, G., & Maertens, M. (2016). Horticultural exports and food security in developing countries. Global Food Security, 10, 11-20. https://doi.org/10.1016/j.gfs.2016.07.007
90. Van der Elst, K., & Williams, A. (2018). Environment and Natural Resources. In R. Serraj & P. Pingali (Eds.), Agriculture & Food Systems to 2050 World Scientific Series in Grand Public Policy Challenges of the 21st Century (pp. 193-214). World Scientific. doi:10.1142/9789813278356_0017
91. van Ginkel, M., & Ortiz, R. (2018). Cross the best with the best, and select the best: Help in breeding selfing crops. Crop Science, 58(1), 17-30. https://doi.org/10.2135/cropsci2017.05.0270
92. van Ginkel, M., Sayer, J., Sinclair, F., Aw-Hassan, A., Bossio, D., Craufurd, P.,… Ortiz, R. (2013). An integrated agro-ecosystem and livelihood systems approach for the poor and vulnerable in dry areas. Food Security, 5(6), 751-767. doi:10.1007/s12571-013-0305-5
93. Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., … Murray, C. J. L. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170), 447-492. https://doi.org/10.1016/S0140-6736(18)31788-4
94. Zabel, F., Delzeit, R., Schneider, J. M., Seppelt, R., Mauser, W., & Václavík, T. (2019). Global impacts of future cropland expansion and intensification on agricultural markets and biodiversity. Nature Communications, 10(1), 2844. doi:10.1038/s41467-019-10775-z
95. Zhang, P., Zhang, J., & Chen, M. (2017). Economic impacts of climate change on agriculture: The importance of additional climatic variables other than temperature and precipitation. Journal of Environmental Economics and Management, 83, 8-31. https://doi.org/10.1016/j.jeem.2016.12.001

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Global Journal of Medical Research: L
Nutrition & Food Science
Volume 21 Issue 1 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

Predictors of Malnutrition among Children Aged 6-59 Months Attending Maternal Child Health Clinic at Ekerenyo Sub-County Hospital in Nyamira County

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GJMR-L Classification: NLMC Code: QU 145

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Ruth Kemunto Nyasimi [α], Dr. Dennis Magu [σ] & Dr. Florence Kyallo [ρ]

Abstract- Malnutrition is the cellular imbalance between supply of nutrients and energy and the body's demand for them to ensure growth, maintenance and specific functions. Malnutrition affects a great number of children globally with 99million underweight and 51million wasted hence remains a public health concern. Prevalence of child malnutrition in Kenya is high with stunting (26.0%), wasting (4.0%) and underweight (11.0%) among children under-five years. The general objective is to determine the predictors of malnutrition among children aged 6-59 months attending maternal child health clinic at Ekerenyo Sub-County hospital in Nyamira County. The study was carried out at Ekerenyo Sub-county hospital located in Nyamira County in Kenya. A descriptive cross-sectional study design was adopted targeting children aged 6-59 months attending maternal child health clinic at Ekerenyo Sub-County hospital. Structured questionnaire was used to collect social economic demographic characteristics, dietary practices and morbidity of children. Systematic random sampling technique was utilized to choose the guardians and care-givers of children aged 6-59 months. Anthropometric measurements wasting (weight-for-height), underweight (weight-for-age), stunting (height-for-age) was taken to determine the nutrition status. Descriptive statistics, Pearson Chi-squire test of association and binomial logic regression. Anthropometric measurement was analyzed using WHO Anthro 2005 Beta Version February 17th, 2006 software. Majority of the children (87.7%) consumed grains and tubers as a dietary practice. A higher percentage(26.4%) of the caregivers earned low monthly income less than Kes 3000. 1.2% of the children were wasted(W/H z-score <-2SD), 6.5% underweight(W/A z-score<-2SD) and 13.4% stunted (H/A z-score <-2SD). Poor nutritional status of children means continued and increased loss of productivity and lives. To achieve optimal results, participation and involvement of mothers and other community stakeholders should be established or strengthened towards addressing child malnutrition.

I. Introduction

a) Background Information

Malnutrition refers to a condition that results from inadequate intake of food which nutrients are too little or too much that it causes health problems including a number of diseases, each with a specific reason related to one or more nutrients and each characterized by a cellular imbalance between the provider of nutrient and energy and the body's insist for them to ensure growth, maintenance and specific functions (WHO, 2006). Malnutrition remains a public health concern as there are 42 million under five years old children who are overweight, 99 million underweight, 51 million wasted and one in four children stunted globally (UNICEF, *et al.,* 2014).

The basic causes of malnutrition are inadequate food intake and infections such as measles, respiratory infections and worm infestation (UNICEF & WHO, 2013). The underlying causes include unsanitary environment, inadequate care of women and children, poor health service and household food insecurity, while the basic causes are such as socio-cultural, economic and political.

Malnutrition results to worsening of health and lower life expectation (Caulfield, *et al.,* 2004; Pelletier and Frongillo 2003) and hinders the potential for countries to reduce poverty (Grantham-McGregor, *et al.,* 2007). Poor health and nutrition, and deficient healthcare derail the potential for cognitive development of about 200 million children under age 5 in developing countries (Ezzati, *et al.,* 2002). This negatively affects school performance, thus lowering adult incomes, which in turn has negative implications for national development (Ezzati, *et al.,* 2002). The joint effects of young children and maternal underweight account for about 15% of the global burden of disease as per (Black, *et al.,* 2003).

Worldwide, the proportion of stunted children under age 5 in the developing world also reduced from 40% to 29% between 1990 and 2008 (UNICEF, 2009). This reduction was mostly in East and Southeast Asia, Latin America and the Caribbean. Despite the global trend of decrease in malnutrition, it remains important in some areas of the earth (Blössner, *et al.,* 2005). 2012 statistics showed that about 25% of the children under 5 years were stunted worldwide. Africa and Asia contributes to the 90% of the children that are stunted where 36% and 56% of the children are affected respectively (UNICEF and WHO, 2013).

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In Sub-Sahara Africa, child under nutrition is one of the most basic challenges for better human development, slowing achievement of the goal of reducing child malnutrition (Kasirye, 2010). Studies on the continent of Africa that report rates of overweight and obesity have concentrated on the South African region and North and West African countries (Monyeki, *et al.,* 2008; Senbanjo and Adejuyigbe, 2007 & Mokhtar, *et al.,* 2007). The Demographic and Health Survey conducted in 2014 indicates that 26% of children are stunted, 4% wasted and 11% underweight, (National Bureau of Statistics Kenya and ICF International, 2015). This is an apparent reduction from previous survey in 2008/9 where 35% of children were stunted, 6.7% wasted and 16.1% underweight (KNBS and Macro, 2010). In spite of this reduction, Kenya portrays a wide variation in rates of malnutrition with marginalized counties of Kilifi, Mandera, Turkana and Bomet posting high rates of stunting that is above 35%. Nairobi, Kiambu have the lowest stunting rates of less than 16%, North Eastern has highest rates of wasting and underweight at 13% and 19%, respectively (KNBS, 2014).

Kenya has made considerable development in providing for the well-being of its citizens; however malnutrition in young children remains a matter of major public health concern. Prevalence of child malnutrition in Kenya is high with stunting (26.0%), wasting (4.0%) and underweight (11.0%) among children 0-60 months old. A study carried out in Siaya district, (n = 175) among children under age 5 reported that kids in their second year of life were more likely to be underweight and stunted. Early introduction to complementary feeding and presence of upper respiratory infection or other sickness in the past month was strong predictors of underweight (Bloss, *et al.,* 2004).

Researches in the country have pointed to the importance of maternal education as a determinant of nutritional status among kids (Gewa, 2010 & Deolalikar, 2010), implying that young children whose mothers have a secondary education are considerably taller than kids whose mothers have not gone to school. In Nyamira County in particular the prevalence of malnutrition among children under five is at 25.5% stunting, underweight at 9.6% and wasting at 4.1% (KDHS, 2014).

b) Statement of the Problem

Despite efforts by the government to provide for the well-being of its citizens, malnutrition in children under the age of five remains a major public health concern in Kenya. Malnutrition is linked with increased morbidity and mortality among children aged 6-59 months. Prevalence of child malnutrition in Kenya is high with stunting among children under-five years old (26.0%), wasting (4.0%) and underweight (11.0%) (KDHS, 2014). In Nyamira County the prevalence of malnutrition among children under five is 25.5% (stunting), underweight at 9.6% and wasting at 4.1% (KDHS, 2014). Although malnutrition is high in rural communities and those living in the slum settings because of poverty and food insecurity, not all children suffer from malnutrition even in food insecure situations. This indicates that other unique context specific factors may be critical in driving malnutrition. The study seeks to establish predictors of malnutrition among children aged 6-59 months attending Maternal Child Health clinic at Ekerenyo Sub-County Hospital in Nyamira County.

c) Study Objectives

i. *Broad Objective*

To establish predictors of malnutrition among children aged 6-59 months attending MCH clinic at Ekerenyo Sub-County Hospital in Nyamira County.

d) Specific Objectives

i. To determine the socio economic demographic characteristics of care givers of children aged 6-59 months attending MCH clinic at Ekerenyo Sub-county Hospital.
ii. To determine the dietary practices of children aged 6-59 months attending MCH clinic at Ekerenyo Sub-county Hospital.

e) Research Questions

What are the social economic demographic characteristics of caregivers of children aged 6-59 months attending MCH clinic at Ekerenyo Sub-county Hospital?

What are the dietary practices of children aged 6-59 months attending MCH clinic at Ekerenyo Sub-county Hospital?

f) Justification

Providing adequate food to meet the nutritional needs of growing children is critical to prevent an increase in malnutrition prevalence, which would lead to excess mortality during the recovery phase of the condition. Nutritional status directly impacts the vulnerability for and the severity of infectious diseases that affect the children. Malnourished children are particularly vulnerable, as they cannot develop the protective compensatory mechanisms that allow healthy individuals to survive during periods of food deprivation. On the other hand, good nutritional status promotes wound healing and improves the postnatal outcomes in both mothers and babies.

g) Study limitations

This was a cross-sectional study done in a facility and therefore that limits the generalization research findings of the study within the population of study. Also the collected data using questionnaires relied heavily on recall basis which is definitely subject to respondent's bias.

II. Literature Review

a) The Concept of Malnutrition

Nutritional status refers to whether or not one is eating correct amounts or types of the required nutrients whereby malnutrition develops incase wrong types and incorrect amounts are consumed. Malnutrition is the lack of the right proportion of nutrients between which nutrients is supplied to the body and what the body needs for growth, maintenance and particular functions (World Health Organization, 2006). Various types of malnutrition have different manifestation. For instance, stunting is a height-for-age Z-score of less than -2 and due to chronic under nutrition. The condition leads to impairment of the normal body growth and the intellectual development. Wasting is weight-for-height Z-score that is less than -2. It can also be defined as Mid-upper Arm Circumference (MUAC) of less than 125mm and it is due to acute under nutrition. Stunting, wasting or both can lead to underweight which is weight-for-age Z-score of less than-2. On the other hand, overweight is weight- for- height Z score or Body Mass Index (BMI) - for-Age Z-score of greater than +2 (United Nations Children's Fund, WHO & World Bank, 2014).

Causes of malnutrition include immediate, underlying and basic causes (UNICEF & WHO, 2013). Instant causes are inadequate food intake and infections such as measles, respiratory infections and worm infestation. Insanitary environment, inadequate care of women and children, poor health service and household food insecurity are all underlying causes of malnutrition. Basic causes are such as socio-cultural, economic and political. Malnutrition therefore occurs when there is longer duration inconsistency between diet use and nutritional wants. Malnutrition remains a public health concern as there are 42 million under five years old children who are overweight, 99 million underweight, million wasted and one in four children stunted globally (UNICEF, *et al.,* 2014).

Prevalence of child malnutrition in Kenya is high with stunting (26.0%), wasting (4.0%) and underweight (11.0%) among children 0-60 months old. In Nyamira County the prevalence of malnutrition among children under five is at 25.5% stunting, underweight at 9.6% and wasting at 4.1% (KDHS, 2014). Numerous studies have reported alarming levels of malnutrition.

b) Indicators of Malnutrition

i. Underweight

A child is considered to be underweight if the measured weight is ranges from 15% to 20% of the normal weight for their age group. The child can be underweight even when the other normal body proportions such as weight-to height ratios are okay (Golden, *et al.,* 2000 & Wittenberg, 2004). Underweight is a significant indication of malnutrition in most cases and this is missed in many instances. Diets with insufficient protein and/or energy lead to the decline of the linear height and the failure to gain more weight or even lose the weight. This comes out clearly when a child is exposed to an acute shortage of food. Research shows that in the developing world, about 129 million children who are below five years are underweight. Out of the 129 million, 10% are severely underweight. In Kenya, the prevalence was (20.3%) as at 2009 compared to 2000 when the prevalence was (21.2%) which shows that Kenya might not meet the MDGs (KNBS, 2010).

ii. Stunting

This is a condition where the growth rate is reduced. In a stunted growth the height for age value is less than -2 standard deviations of the WHO child growth standard median (WHO, 2014) compared to wasting and underweight, stunting in infants and children under the age of five is considered to be a worse problem. Stunting is an indicator of either an illness or nutritional deficiencies which might happen during a phase of growth and development (Shetty, 2002 & UNICEF, 2009) the first sign of malnutrition in children is the stunted growth. In the developing world, about 195 million children of less than 5 years are affected. In Africa, one in three children is affected by stunted growth (Piercecchi Marti, *et al.,* 2006). 2012 statistics showed that about 25% of the children under 5 years were stunted worldwide. Africa and Asia contributes to the 90% of the children that are stunted where 36% and 56% of the children are affected respectively (UNICEF and WHO, 2013). In Kenya stunting rates still remain high at 26% (KDHS, 2014).

iii. Wasting

A child is moderately wasted when the weight for height is less than –2 SD from the mean. If the child weight for height is less than 70% of the median and is equal to a standard deviation score of –3SD then the child is severally wasted (WHO, 2014). Moderate and severe wasting represents an acute form of malnutrition and children suffering from wasting are at a greater risk of dying (Williams, 2005). In 2011, the proportion of children below the age of five years who were found to be wasted was about 52 million globally and 1 out of every 10 children in Africa. The study showed that weight for age was statistically insignificant to malnutrition (Liu et al., 2012). In Kenya the prevalence of wasting is at 4% (KDHS, 2014). Wasting can be surmount by optimal feeding but may have permanent debilitating impacts such as cognitive impairment.

c) Socio-Economic Status of Women and Nutritional Status

Child under-nutrition is highly associated with the women's lack of the capacity to support child nutrition (Walker, *et al.,* 2007). Also, the inability of the

women to have access or control the resources for their wellbeing has a negative impact on the nutrition and the health of the children (UNICEF, 2013). Low socio-economic status of women is also associated with poor maternal nutrition before and even during pregnancy and this has a negative impact on the unborn baby resulting to low birth weight babies who are highly likely to develop malnutrition (UNICEF, 2013). A study in Uganda demonstrated that mother's education is the best prediction of the child's health in a community and not the household assets, land ownership or father's education (Wamani, *et al.,* 2004). There was a significant relationship in the current study between low socio-economic status of women and the child malnutrition with the children whose mothers had no employment, formal education and had their husbands made decisions on the food to be bought or cooked being the mostly affected. Sixty five percent of children whose mothers had no formal education were found to be malnourished compared to only 15% of the children whose mothers had formal education. Similarly, 63% of children from households where the food decisions were determined by the husband were discovered to be malnourished as compared to only 11% of children from households where the food decisions were influenced by children's needs. Thirty one percent of children whose mothers were housewives were found to be malnourished as opposed to only 6% of children whose mothers were self or formally employed. The community under study believes that women should not be allowed to make any decision even in the household. The women therefore become over dependent on their husbands for financial help as well as decision making. This explains the relationship between the malnourished children and socio-economic status of women in the study. Findings by ACF (2014) revealed that low level of maternal education was an important risk factor for child malnutrition among the same community that also led to early pregnancies and inadequate birth spacing.

High socio-economic status of women on the other hand prevents early marriages, early childbearing and having large families. Findings by Lisa, *et al.,* (2003) also supported this where high women status was found to have a positive influence on children nutrition status leading to a reduction in stunting and wasting. Frangilo, *et al.,* (1997) also demonstrated that high female literacy was one of the most significant factors linked with lower prevalence of wasting in children. This explains why 65% of children in the present study whose mothers had no formal education were malnourished. Majority (54%) of women in the study area stayed at home and waited to be provided for by their husbands hence had no control over what or how much to be offered for household use. This can then explain as to why 31% of children whose mothers were housewives were malnourished compared to only 6% of children whose mothers were employed.

Education level of an individual dictates the socio-economic status within a community as education is key to many socio-economic services. The level of education among women in the study area was low and may be attributed as to why 65% of children whose mothers did not have any formal education were found to be malnourished. Among other things woman with no education will not be in a position to prioritize the household needs or make crucial decisions that affect the child nutrition and health in general. A woman of low socioeconomic status has also low bargaining power within the household and this has a negative impact on nutrition and health of the children (Walker, *et al.,* 2007). This is demonstrated in this study whereby 63% of children from the household where the food decisions were made by the husband were found to be malnourished. Some communities have a negative attitude towards women and would not involve them in any decision making and this further explains as to why a higher (63%) percentage of malnourished children was found in households where the husband was the decision maker on food consumption. The lack of decision making power of a woman in household and in society at large among the community under study was also demonstrated in an earlier study (ACF, 2014).

d) Dietary Practices of Children Aged 6-59 Months

One of the most efficient customs of improving child health is the use of optimal IYCF (WHO, 2003 & WHO, 2009). The morbidity and the mortality rate of children can be lowered by suitable feeding. Suitable feeding can also lower the risk of chronic diseases in the later life of the children (WHO, 2015).

The following practices have been proposed by the WHO and the UNICEF to ensure there is optimal use of IYCF: initiation of breastfeeding immediately after birth within one hour, breastfeeding exclusively for the first six months and introducing foods at six months that are nutritionally adequate and safe as the children are breastfed to two years and even beyond (WHO, 2003 & WHO, 2015).

The IYCF (infant and young children feeding) was completely established by the Kenyan in 2007 (UNICEF, 2009). Other non-governmental agencies also contributed to the increase of the programme. However, Kenya has not attained the WHO goal of 90%. It is still below the world prevalence which is at 37%. Kenya has the lowest exclusive breastfeeding rates in east Africa region where the prevalence has been estimated to be 47% (UNICEF, 2011).

i. *Breastfeeding*

Breastfeeding plays an integral part in the reproductive process. It is an unequalled way of giving ideal foods to infants for their development and growth. Breastfeeding has crucial outcomes on the health of the child and the mother (Duan, *et al.,* 2018).

Breastfeeding has short and long term benefits for the child. It is essential for the optimal growth of the child. The infections and the mortality rates are reduced through breastfeeding. Also, breastfeeding increases the motor and the mental development. Moreover, it protects the children against obesity and the other metabolic disease that affect people in their later lives (Kimani-Murage, *et al.,* 2011 & Rollins, *et al.,* 2016).

Research has shown that half of the diarrhea infections and a third of the respiratory diseases can be eliminated through breastfeeding (Victora, *et al.,* 2016). The breast milk has antibodies which help in fighting of diseases and protecting the children from respiratory infections and the diarrhea (Dòrea, 2009).

Some of the benefits of breast milk include: providing the baby with anti-bacterial, anti-parasitic and anti-viral agents which make the immune systems of the infant strong. Avoiding to breastfeed infants or breastfeeding the partial exposes them to the risks of diarrhea and the other infections (WHO, 2010). The infants' immune system and the response to vaccination can be stimulated by breastfeeding (Dòrea, 2009). Breast milk has been categorized as a personalized medicine for the infants (Victora, *et al.*, 2016).

The first milk produced by a mother is called colostrum. Colostrum is rich in antibodies and has anti-infective properties that are very high. It serves as the first immunization for the infants (Bartle, 2013 & WHO, 2010). The IQ (intelligent quotient) of the infant is also improved through breastfeeding (Kramer & Kakuma, 2004). A higher IQ has always been associated with higher earnings and higher quality of life (Victora, Bahl, Barros, França, Horton, Krasevec, Murch, Sankar, Walker & Rollins, 2016). Other benefits include; neurological, visual as well as the motor development, protecting the infants against asthma, allergy and the other skin diseases. Moreover, breast milk protects children even in their later lives from conditions such as obesity and diabetes (UNICEF, 2011).

Optimal breast feeding is one of the most effective and efficient defensive measures for the survival of the child (Bartle, 2013 & Rollins, *et al.,* 2016). Statistics taken in 2015 showed that the lives of about 800, 000 children below the age of five years could be saved by scaling up the breastfeeding levels (Black, *et al.,* 2013; Victora, Barros, Franca, Horton, Krasever, Murch, Sanar, Walker & Rollins, 2016). Taking a balanced diet and optimal breastfeeding has an important impact on the health of the infants than immunization and clean water (Bartle, 2013).

ii. *Initiation of Breastfeeding*

There is proof that suggests that when breastfeeding is initiated within one hour after birth, the infants are protected from infections and deaths of the newborn (WHO, 2015). A research done in Ghana (Zandoh, Quigley, Amenga-Etego, Owusu-Agyei & Kirkwood, 2006) showed that breastfeeding within the first few hours after birth could up to 22% of neonatal deaths. It was also revealed that breastfeeding with the first day could prevent 16% of deaths. On another similar study, Nepal (Mullany, Katz, Li, Khatry, LeClerq, Darmstadt & Tielsch, 2008) revealed that about 19.1% of all neo-natal deaths that occur can be avoided through the initiation of breastfeeding within the first hour of a child's life. It is essential to initiate breastfeeding within the first hour after birth.

iii. *Exclusive breastfeeding*

Breastfeeding has crucial impacts on the health of the mother and the child. It plays an integral part in the reproductive process; research has shown that exclusive breastfeeding cannot be equaled by other meals (Duan, *et al.,* 2018).

In the first six months of a child's development, breast milk with no other addition is enough to provide the needed nourishment. Breast milk has all the nutrients, antibodies and the immune factors that are needed by the infant (WHO, 2003). Mortality in the children can also be reduced by breastfeeding (Kramer & Kakuma, 2004). Out of the 10 million deaths of infants that happen every year of children under the age of 5, breastfeeding could reduce the figure by 1.4 million deaths (Black, *et al.,* 2008 & UNICEF, 2011).

At six moths children become more active. It is expected that at this time, they could have doubled their birth weight. At this stage, they need more nutritional foods for rapid growth. It is therefore essential that other foods are introduced at this stage as exclusive breastfeeding could not be sufficient for them (Jones, Steketee, Black, Bhutta & Morris, 2003).

Mothers also benefit from exclusive breastfeeding of their young ones. Breastfeeding reduces the risks of ovarian and breast cancer. Moreover, it helps the mothers in losing the weight gained during pregnancy. Also, it is a method of birth control which is known as lactation amenorrhoea method. This can help in spacing pregnancies (Labbok, Clark & Goldman, 2004; Rollins, *et al.,* 2016).

Breast milk has high quality nutrients for the children (WHO, 2003; WHO & UNICEF, 2008). Between 6 months to 12 months, half of the energy needs of the child can be provided by breast milk. Between 12 to 24 months a third of the child's energy needs can be provided by breast milk (Dewey & Brown, 2003). Breast milk therefore becomes very significant for the child especially in a setup where the resources are constrained (WHO, 2009).

iv. *Complementary Feeding*

Complimentary feeding is done at the stage of six months where the children are introduced to eating foods (Dewey & Brown, 2003). Sometimes because of inadequate feeding, this period can be marked by a reduction in the child's nutritional status. This is evident

in the low and middle income countries. The deficit that occurs during this period might be hard to recompense in the later stages of life (Dewey & Brown, 2003; FAO, 2015 & WHO, 2009).

To prevent malnutrition, factors such as promotion of the optimal breastfeeding, micronutrient supplementation, introduction of appropriated feeding in a timely manner and child care are some of the feasible measures that could be put in place (Saleh, *et al.,* 2014).

The method of feeding that is chosen and the frequency of the meal should be appropriate for the age of the child. The child should be encouraged to take enough food even during a time of illness (WHO, 2003 & WHO, 2005). It is unfortunate that most caregivers receive advice on feeding and information from unskilled sources such as the mothers and the mother in-laws. This makes it difficult for them to make out the best of food in the households due to the lack of knowledge of the best food for the young children, also the cultural practices and beliefs determines the type of food the children are given (Waswa, 2015).

Also, the knowledge and skills that women acquire from schools help them in determining when the children are ill so that they can seek treatment (Abuya, 2012). Use wrong feeding methods during complimentary feeding period have proven to negatively impact the health of the child. It is therefore important that women are educated on the interventions on infants and feeding of the young children. A study done on the education given to women on complimentary feeding showed that the children of mothers who received nutritional education improved both in height and weight (Imdad, *et al.,* 2011).

v. *Practicing Responsive Feeding*

Optimal complimentary feeding is a factor of what is fed, how it is fed when and by whom the child is fed with (Pelto, Levitt & Thairu, 2003). In receptive feeding, the infants are only fed when they express hunger and no specific schedule if followed to feed them (Black and Aboud, 2011).

In receptive feeding system, the children are fed when they are sensitive to their hunger and the satiety cues. In this case, the caregiver has the responsibility of watching the children and responding to the cues for hunger and satiety from the children. Infants should not be forced to eat. The feeding should be done until they indicate to be full. The child should be breastfed anytime that they demand to be breastfed. This can be eight to 12 times in a period of 24 hour (WHO, 2009).

Responsive feeding is meant to improve the attentiveness and the interest of the child while feeding. It also enables them to communicate their needs to those who are their caregivers using some distinct signals and successful progression to the independent feeding (Black and Aboud, 2011; Bentley, *et al.,* 2011 & Eshel, *et al.,* 2006). Responsive feeding is therefore used as a key to a healthy caregiving behavior. However, this technique might not be effective when a child is ill; when illness strikes, the intake of fluid and nutrient should be higher to cater for the losses that occur during this time through fever, diarrhea and vomiting (Dewey, 2015).

vi. *Food Consistency*

At six months, the kids can take smashed and semisolid foods. Finger foods can be eaten by the children at eight months. The finger foods are the snacks that can only be eaten by the child alone. As the infant gets older, there should be an increase in the foods take depending on the ability of the child and the requirements. After one year, the children should take the foods just as the ones taken by the rest of the family. The foods provided should be dense in nutrients. It is essential that a variety of foods are included while preparing food for the young ones so that the nutritional wants are met (WHO, 2005 & WHO, 2009).

The use of micronutrient sprinkles with IYCF education reduces anemia and iron deficiency compared with IYCF education only (Jack, *et al.,* 2012). With low intake of fortified foods, MNPS, poor dietary diversity, low minimum meal frequency, low minimum acceptable diet and meager intake of fortified foods in Wajir children at risk of micronutrient deficiency. Young ones should be given sprinkles and sustained until 2 years in order to cover up for the most vulnerable period.

vii. *Meal Frequency and Energy Density*

The amount and number of feedings given to an infant is dependent on the food's energy density. The frequency of feeding the child the complementary foods should be higher than the previous one as the child gets older for an infant who is well breast fed, the complimentary foods should be given two to three times in 24 hours from the sixth month to the eight month. The amount should then be increased to three to four times a day onward up to the age of two years. The snacks are the meals that are eaten between the meals and they can be taken by the child alone without the caregiver. Snacks are easily prepared and they are convenient. Examples of the snacks that are considered nutritious are the fruits and bread with peanut paste (Brown, Dewey & Allen, 1998; WHO, 2003).

For the children that are not well breastfed, they should be given meals that include milk. The milk and the other foods should be provided at least three to four times a day with the additional snacks two times a day as it may be desired. The number of feeding could also depend on the energy density of the foods that are provided. More recurrent meals should be given if the energy density of the foods is low (WHO, 2005). Households are regarded as food secure when everyone has access to enough food at all times to meet dietary supplies from either own production,

purchase or food safety net programming (Simon, 2012). Moreover, one must consider the capacity of the body to utilize the food eaten, which is dependent on adequate knowledge on food nutrient, child care practices, health and sanitation (WHO, 2015).

viii. Providing a Variety of Nutrient-Rich Foods

Despite the advantages of breast milk, it has a low amount of some minerals such as iron and zinc. Therefore, the children should be introduced to other meals such as meat, fish, eggs and poultry. Such meals are rich in the minerals that lack in breast milk. Calcium can be obtained from the milk and the milk products and should also be given to the children. At a younger age, a diet which does not have animal products cannot meet all the nutritional needs of the children (WHO, 2003 & WHO, 2005).

Children develop rapidly during their first two years and as a result, their bodies have high nutritional needs. The caregiver should therefore notice the nutrient content of the foods that are given as complementary to ensure that all the nutritional needs are met. It is also advisable that fortified complimentary foods or the vitamin-mineral supplements are given to the young ones (WHO, 2009).

Fat is also a crucial content in the diet. Fats can be obtained from paste made from nuts and other seeds. Vitamin A should also be included in the diet of the child. Vitamin A can be obtained from fruits and vegetables that are colored, vitamin A fortified oils and eggs. Foods rich in vitamin C should also be consumed to increase iron absorption (WHO, 2003).

e) Conceptual Framework

The conceptual framework in Figure 1.1 indicates the relationship between independent variables (predictors) and dependent variables.

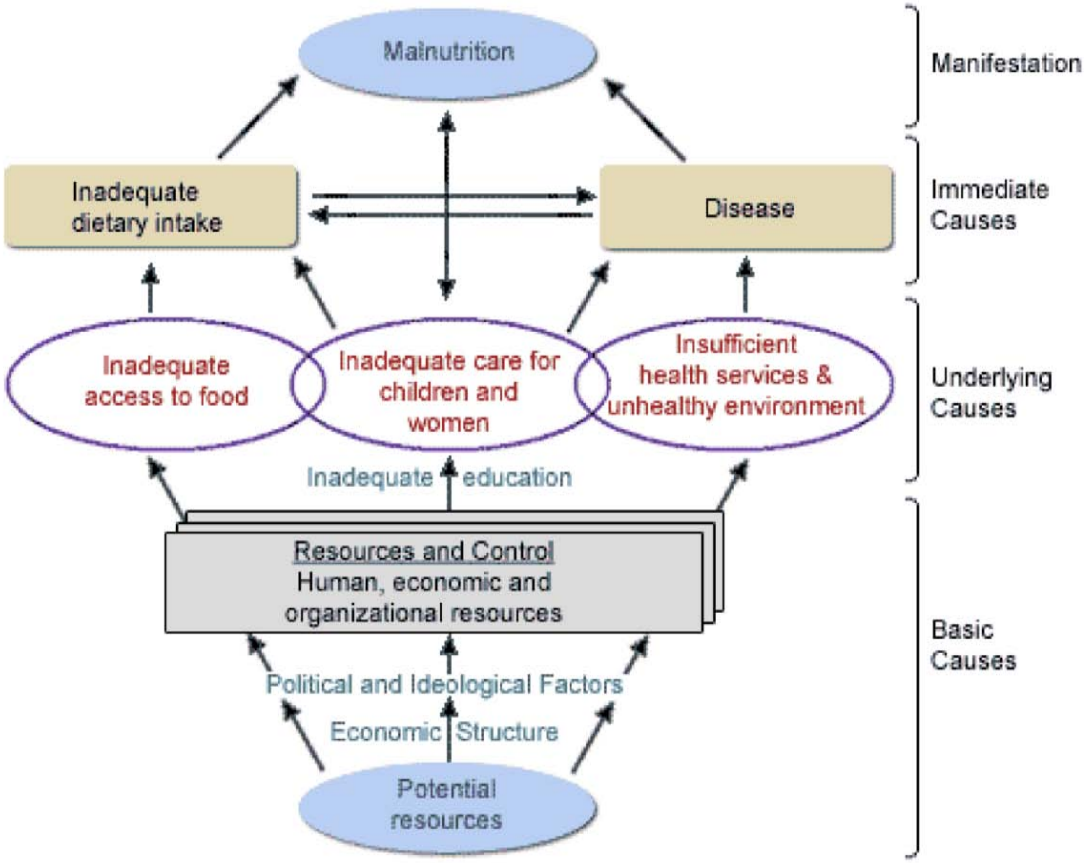


Figure 1.1: Conceptual Framework for Malnutrition adopted and modified from UNICEF (1998)

III. Materials and Methods

a) Study Site

The study was conducted at Ekerenyo Sub-county Hospital in Nyamira County. The hospital is located in Nyamira North Sub-County (North Mugirango Constituency). It has a bed size of eighteen. Nyamira County has a population of 598, 252. The County borders the following counties; Homabay to the north, Kisii to the west, Bomet to the south east and Kericho to the east. The area covered by the County is 899.4km2.

b) Study Design

A descriptive cross-sectional study design was used to establish the predictors of malnutrition among children aged 6-59 months attending MCH clinic at Ekerenyo Sub-county Hospital.

c) *Study Population*

The study population was children aged 6-59 months attending MCH clinic at Ekerenyo Sub-county Hospital.

i. *Inclusion Criteria*

- Children aged 6-59 months attending MCH clinic at Ekerenyo Sub-county Hospital.
- Guardians and caregivers of children aged 6-59 months who will give consent to participate in the study attending MCH clinic at Ekerenyo Sub-county Hospital.

ii. *Exclusion Criteria*

- Guardians and caregivers of children aged 6-59 months who are unable to neither communicate nor give consent attending MCH clinic at Ekerenyo Sub-county Hospital.
- Children aged 6-59 months whose caregivers declined to participate in the study attending MCH clinic at Ekerenyo Sub-county Hospital.

d) *Sampling*

i. *Sampling Procedure*

The researcher employed systematic random sampling technique to select guardians and care-givers of children aged 6-59 months attending MCH clinic at Ekerenyo Sub-county hospital who were respondent into the study. The researcher picked the first who meet the inclusion criteria child randomly and there after every child who meet inclusion criteria and whose caregiver consented to participate was enrolled in the study. This was done every day of the week until the sample size was achieved for two months.

ii. *Sample Size Determination*

Using Cochran formula, (Cochran, 1977) a sample size was determined based on Kenya national prevalence of stunting which is estimated at 26% (National Bureau of Statistics-Kenya and ICF International, 2015). Cochran formula: $n=z^2 (pq)/e^2$

n = 1.96 x1.96 (0.26 x 0.74) 0.05x0.05
n = 295.649
n = 300
n = Sample size
z = Linked to 95% confidence interval (1.96)
p = Expected prevalence (as fraction of 1) (0.26)
q = 1-P (expected non-prevalence) (0.74)
e^2 = Desired precision of 0.05 for this study.

e) *Study Variables*

i. *Dependent Variable*

The dependent variables include malnutrition identified as stunting, wasting underweight.

ii. *Independent Variable*

Maternal characteristics religion, family incomes, level of education, occupation and child characteristics; age, sex, birth order, birthplace and mode of delivery were direct independent variables. Household characteristics; family size, marital status of caregiver, ownership of livestock, dietary practices and diseases two weeks before interview indirectly influenced malnutrition.

f) *Data Management*

i. *Data Collection Tools*

- Questionnaire

A questionnaire was used to gather data on social economic demographic characteristics of guardians and caregivers, dietary practices, and children's morbidity. The interview was conducted by the research team (the researcher and two research assistants) who were responsible for administering the questionnaire and entering all the data. The research assistants read out the question to the participants and then document the answer by either ticking, circling or writing the answer given by the participant on the space provided.

ii. *Anthropometry*

Anthropometric measurements were conducted by the researcher and two research assistants, trained in all aspects of data collection procedures. The researcher was assisted by one research assistant to take the measurement of weight and height of every child enrolled while the second assistant recorded the measurements in the questionnaire. The weights were measured to the nearest 0.1 kilograms using a portable bathroom scale. The heights were measured to the nearest 0.1 centimetres using the height board.

- Procedure of Measuring the Heights of Children

A child whose height was 85cm and below was made to lie down on a measuring board. The child's head was supported by one hand while the rest of the body was supported by the other; the child was lowered into the measuring board. The child's head was placed against the base of the board with the knees firmly pressed against the board and foot piece firmly against the child's heel. The assistant ensured that the child looked up straight with line of sight perpendicular to the ground. Children whose height was above 85cm were measured standing on a height scale. The child stood straight on the board with knees firmly held against the measuring board. The head piece was lowed until the child head and measurements were taken. All the measurements were taken to the nearest 0.1cm. The readings were recorded in centimeters.

- Procedure of Weighing Children

Children were weighed using infant electronic weighing scale model RCS-20 designed to take up weight of up to 20 kilograms. Children clothes were removed leaving them with a vest only. Older children above 12 months were weighed while seated on the

scale, while those below 12 months were weighed lying supine on the scale. The weight was taken to the nearest 0.1kg.

- Procedure of Measuring Mid Upper Arm Circumference (MUAC)

The child's shoulder tip was located using fingers. A right angle was made by bending the child's left hand elbow. Using a MUAC tape was the length from the tip of the shoulder to the tip of the elbow was measured to get the midpoint. The midpoint was marked using a pen. The child's arm was wrapped using a MUAC tape around the mid- point to measure the circumference. The readings were recorded to the nearest 0.1 centimeters.

g) Data Management and Analysis

i. *Data Entry*

Data was entered using Microsoft Access Software. Errors were minimized by cleaning and rechecking all data entries with original data forms. The data was then imported into excel which was used for coding and validation.

Backup of the data was done and filled questionnaires were cross-checked then stored in a lockable cabinet accessible only to research personnel o as to ensure privacy. The data was analyzed using quantitative techniques. Quantitative data was analyzed using Statistical Package for Social Sciences (SPSS 21). Descriptive statistics was used to sum up the sample population into percentages, frequency distributions and charts.

ii. *Data Analysis*

Anthropometric data was analyzed using WHO Anthro 2005 Beta Version February 17, 2006 software. The anthropometric indices were expressed in terms of z-scores (Height for Age, Weight for Height and Weight for Age) and reflected as adequately nourished, stunted, wasted or underweight in comparison to a reference population of well- nourished children provided by World health organization (Rutledge & Boyd, 2010). The z-scores (or Standard Deviation score) are the deviation of the value of the child measurements from the median value of the reference population, divided by the standard deviation of reference population.

$$\text{Z-score or SD-score} = \frac{\text{Observed value} - \text{Median reference value}}{\text{Standard deviation of reference population}}$$

Z-scores were interpreted as normal when the calculations were >-2 standard deviation, moderate when they were -3 to <-2 standard deviations and severe, when the readings were<-3 standard deviations in comparison to the reference population of healthy children using data from across the world for all indicators.

Statistical Package for Social Scientists (SPSS) version 21 was used to analyze numerical and categorical data. After questionnaires were counter checked for completeness and legibility, double entry of all the data into SPSS computer program and database established for all variables. Descriptive statistics on demographic characteristics of respondents, socio-economic, household characteristics and characteristics of study children were analyzed. Measures of central tendencies, dispersion and percentages were analyzed and presented as tables and bar graphs. Across-tabulation using Chi-square test of association was used to assess the association between dependent variables; wasting, underweight and stunting and independent variables; demographic characteristics of respondents, socio-economic factors, child characteristics, feeding practices, and household characteristics. Chi-square values, degree of freedom and p-values described the association and significance level.

To determine the predictive factors, a binomial logistic regression was modeled. All variables that were found to be significant at bivariate level were entered into the regression model. The logistic regression model adapted for this study;

Let;

$$P1 = Pr(y=1) \mid x=xi)$$

Then,

$$\text{Log } (P1)/(1\text{-}Pr) = \text{Logit } (P1) = Bo + B1Xi$$
$$= P1/(1\text{-}P1) = \text{Exp } (Bo + B1Xi)$$
$$= P1 = \exp(Bo + B1X1)/(1 + \exp(Bo + B1Xi))$$

h) Ethical Considerations

Ethical clearance for the study was obtained from University of Eastern Africa, Baraton Ethical Review Committee. Participants for the study were informed about the purpose of the study. Confidentiality was retained by giving a reason for the intention of the study and obtaining permission from the participants. Information received from the study was not disclosed to illegitimate people; only data needed was gathered and utilized for the intention of study. The participants were given an option to withdraw from the study without consequences. The identity of the patient was protected by not using their names or other information identifying the participant. All questionnaires were collected soon after each interview and kept in lock and key.

IV. Results and Discussion

a) Socio economic and demographic characteristics of the respondents

Two hundred and sixty one caregivers of children between the ages of 6 to 59 months were interviewed using structured questionnaires. The mean maternal age was 25.5(± 4.91) years and almost a half (45.6%) related with their mother and less than a quarter (4.2%) related with others. Nearly one third (30.7%) had attained secondary level education and a minimal number (5.4%) had attained tertiary education. Half the

respondents (50.6%) were Christians, (27.2%) protestant and (22.2%) were other denominations. Nearly a third (36%) of the families had two children each while small a number (3.4%) had more than five children each. More than three thirds of the women (78.5%) were married and less than a quarter were (4.2%) divorced/widowed and (17.3%) were single. Almost half of the households (46.7%) had 5-7 people compared to (0.8%) of the largest families who had more than 10 persons per household. The table 4.1 below illustrates the social-economic demographic characteristics of caregivers of children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital.

Table 4.1: Socio Demographic Characteristics of Caregivers

Variable	Frequency	Percentage (%)
Caregivers' Age in Years (N=261)		
<20	27	10.3
21-30	189	72.5
31-40	40	15.3
>40	5	1.9
Relationship with Child(N=261)		
Mother	119	45.6
Aunt	74	28.4
Sister	57	21.8
Others	11	4.2
Level of education(N=261)		
Non-formal learning	73	28.0
Primary school	65	24.9
Secondary school	80	30.7
Technical/polytechnic	29	11.1
College/University	14	5.4
Religion N=261		
Christian	132	50.6
Protestants	71	27.2
Others	58	22.2
Number of children N=261		
One	34	13.0
Two	94	36.0
Three	81	31.0
Four	43	16.5
More than five	9	3.4
Marital Status (N=261)		
Married	205	78.5
Divorced	7	2.7
Widowed	4	1.5
Single	45	17.3
People living in the households N=(261)		
2–4	111	42.5
5-7	122	46.7
8-9	26	10.0
Above 10	2	0.8

Source; (Research Findings, 2019)

b) Socio Economic characteristics among the Respondents

Approximately a third (33.0%) of the house head were farmers, a quarter were business persons and in formal employment (26.4%) and (25.3%) respectively. The study established that monthly earnings were less than Kes. 3000 for (26.4%) while (24.9%) for those earning between Kes. 3000-5000 and (10.7%) between Kes. 20000-30000. Almost half (44.8%) of the respondents were self employed, while (40.6%) were

housewife and (14.6%) had other occupations. Majority (40.6%) of the respondents acquired wood fuel, a third (30.3%) used charcoal, (13.0%) used paraffin, (9.6%) used cooking gas, and (6.5%) used electric power as a source of fuel. On affordability of the source of fuel, almost half (44.1%) of the respondents said it was expensive, (42.1%) was affordable and (13.8%) affordable. The highest number of the respondents own livestock (63.2%). Three quarter of the respondents kept (55.2%) poultry, (17.6%) goat, (24.2%) cow, and a small proportion (3.0%) own sheep. The table below illustrates the distribution of socio-economic characteristics of respondents.

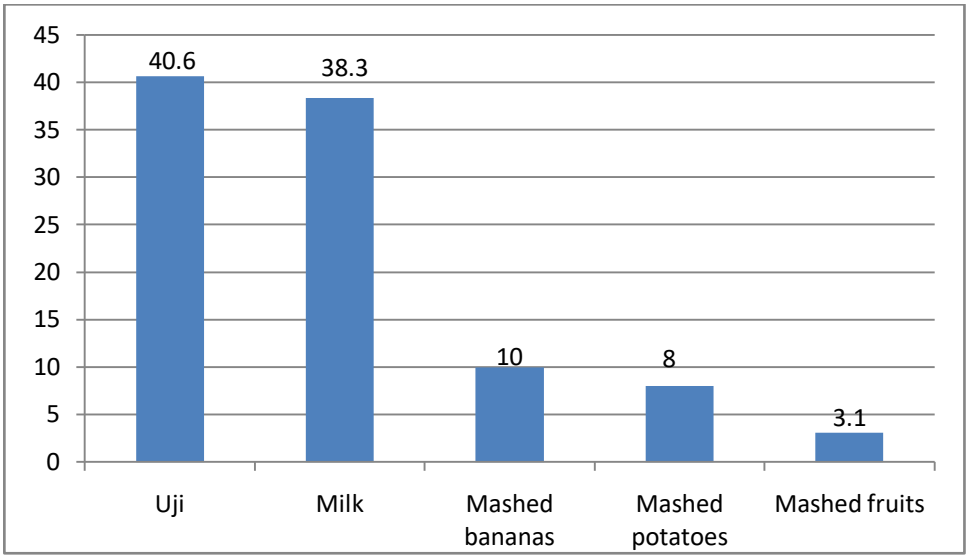
Table 4.2: Distribution of Socio Economic Characteristics of Respondents

Variable	Frequency	Percentage (%)
Occupation of Head of the House (N=261)		
Business	69	26.4
Formal Employment	66	25.3
Farmer	86	33.0
Others	40	15.3
Monthly incomes Kes.(N=261)		
Less than 3000	69	26.4
3000-10000	65	24.9
10000-15000	60	23.0
15000-20000	39	14.9
20000-30000	28	10.7
Occupation of caregiver (N=261)		
Housewife	106	40.6
Self employed	117	44.8
Others	38	14.6
Source of fuel (N=261)		
Wood fuel	106	40.6
Charcoal	79	30.3
Paraffin	34	13.0
Cooking Gas	25	9.6
Electric Power	17	6.5
Affordability of Source of Fuel (N=261)		
Expensive	115	44.1
Moderate	110	42.1
Affordable	36	13.8
Livestock ownership (N=261)		
Yes	165	63.2
No	96	36.8
Type of Livestock kept (N=165)		
Goat	29	17.6
Sheep	5	3.0
Poultry	91	55.2
Cow	40	24.2

Key: Kes = Kenya ShillingsSource;
(Research Findings, 2019)

c) *Distribution of Type of Foods Introduced among children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital.*

The study findings reveals the type of food introduced as illustrated in figure 4.2 below. The main food introduced was uji (40.6%), milk (38.3%), mashed bananas (10%), 21 (8%) mashed potatoes (8%) and a small proportion of mashed fruits (3.1%).

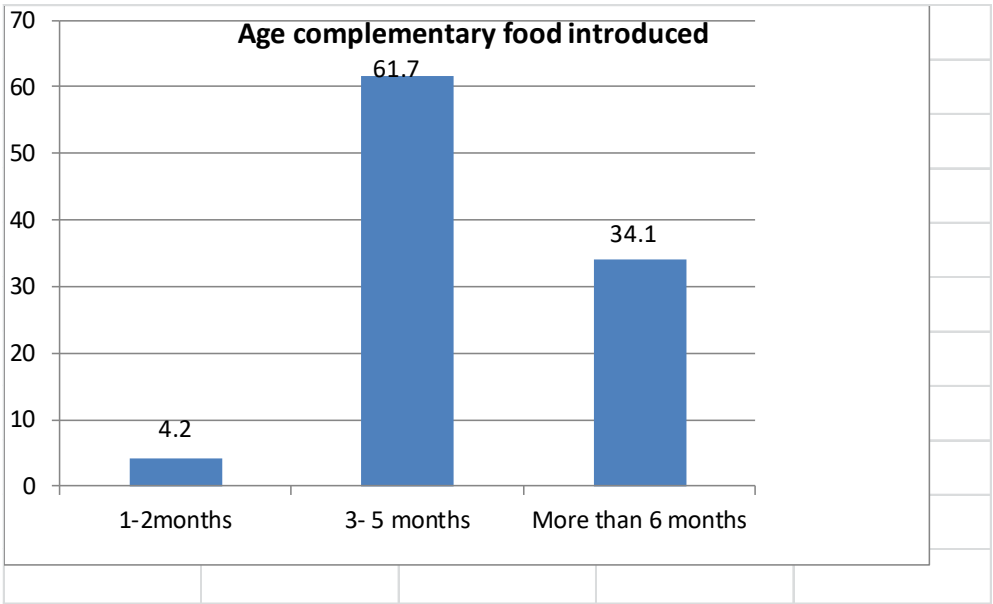


Source; (Research Findings 2019)

Figure 4.1: Distribution of Type of Foods Introduced among children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital

d) *Distribution of age complementary food was introduced among children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital*

The research findings illustrates that complimentary feeds introduced among children(61.7%) was 3-5 months, (34.1%) was at more than 6 months and lastly (4.2%) introduced at 1 month to 2 months.

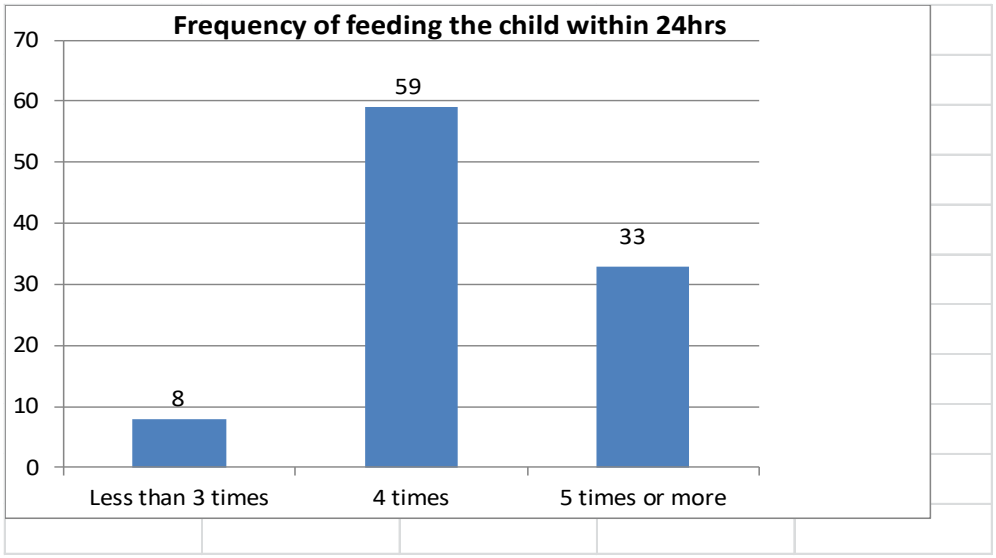


Source; (Research Findings, 2019)

Figure 4.2: Distribution of age complementary food was introduced among children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital

e) *Distribution of frequency of feeding within 24hrs among children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital*

On how many times the child is fed within 24 hours, (59.0%) fed their children 4 times, (33.0%) fed the children 5 times.

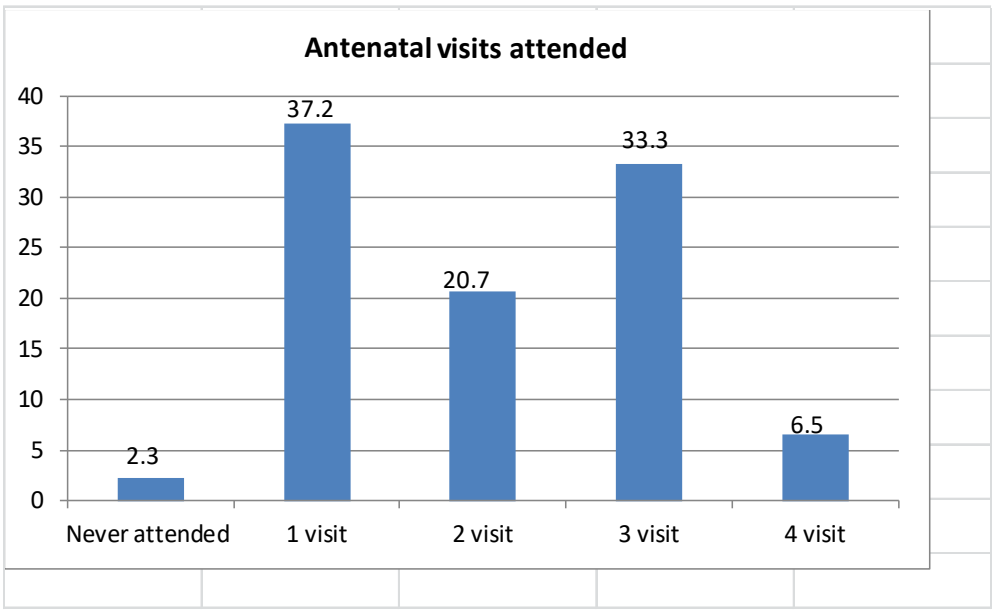


Source; (Research Findings, 2019)

Figure 4.3: Distribution of frequency of feeding within 24hrs among children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital

f) Distribution of frequency of antenatal visits attended among children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital

In figure 4.4 below shows more than one third (37.2%) had attended antenatal visit once, (33.3%) had three antenatal visits, (20.7%) attended 2 visits, (6.5%) attended 4 antenatal visits and a small proportion (2.3%) never attended antenatal visits.



Source; (Research Findings, 2019)

Figure 4.4: Distribution of frequency of antenatal visits attended among children aged 6 to 59 months attending MCH clinic at Ekerenyo Sub-County Hospital

g) Dietary Practices

The researcher established the dietary practices among children aged 6 months to 59 months as presented in (Table 4.4).

Table 4.4: Distribution of Dietary Practices Data

Variable	Frequency	Percentage (%)
Heard about balanced diet N=261		
Yes	184	70.5
No	77	29.5
Source of dietary practices information(N=184)		
TV	33	17.9
Radio	53	28.8
Healthcare workers	34	18.5
Friends	28	15.2
Newspapers	36	19.6
Food groups consumed in the households		
Grains and tubers(N=261)	257	98.5
Legumes and nuts(N=261)	236	90.4
Dairy products(milk, yogurt, cheese(N=261)	201	77.0
Flesh foods(meet, fish, poultry and liver/organ meats(N=261)	2	0.8
Eggs(N=261)	9	3.4
Vitamin-A rich fruits and vegetables(N=261)	14	5.4
Other fruits and vegetables(N=261)	96	36.8
Acquire foods(N=261)		
Own farms	140	53.6
Food Aid	13	4.9
Shops	69	26.4
Purchase at roadside	39	14.9
Frequency of feeding (N=261)		
On demand	110	42.2
2 Times a day	86	32.9
3 to 4 times a day	65	24.9
Child's food intake in the last 24 hrs		
Grains and tubers(N=261)	229	87.7
Legumes and nuts(N=261)	81	31.0
Dairy products(milk, yogurt, cheese(N=261)	187	71.6
Flesh foods(meet, fish, poultry and liver/organ meats(N=261)	14	5.4
Eggs(N=261)	21	8.0
Vitamin-A rich fruits and vegetables(N=261)	37	14.2
Other fruits and vegetables(N=261)	129	49.4

Source; (Research Findings, 2019)

Almost three third (70.5%) of caregivers have heard about balanced diet from different segments. More than a quarter (28%) got informed from radio, and 19.6%, 18.5%, 17.9% and 15.2% were informed from the newspapers, healthcare workers, television and friends respectively. The study established that majority of caregivers feed on grains and tubers (98.5%), legumes and nuts (90.4%), milk was (77%) and fruits and vegetables (36.4%). (5.4%) vitamin- A rich fruits and vegetables, (3.4%) eggs, and a small proportion of (0.8%) took meat. The study established that majority (53.6%) acquired food from farms, (26.4%) acquire foods from shops, (14.9%) purchase at roadside and (4.9%) acquire food from food aid to meet their needs. Majority caregivers feed their children on demand

(42.2%) and give grains and tubers (87.7%) in the last 24 hours as illustrated in (table 4.4) above.

h) Bivariate Analysis

i. *Association of dietary practices on the nutritional status of children aged 6-59 months attending baby well clinic at Ekerenyo sub county hospital*

The study findings established from a total of 261 caregivers that grains and tubers as a dietary practice was associated with malnutrition on wasting ($\chi 2$ =14.578, p-value= 0.056). The effect of grains and tubers as compared to other dietary practices was not statistically significant on underweight ($\chi 2$ =9.145, p-value=0.147) and stunting ($\chi 2$ =3.255, p-value= 0.789). This is illustrated in the table 4.5 below.

Table 4.5: Association of dietary practices on the nutritional status of children aged 6-59 months attending baby well clinic at Ekerenyo sub county hospital

Variable	WHZ<-2SD		WHZ≥-2SD		$\chi 2$	Df	p-value
	n	%	n	%			
Dietary Practices (N=261)							
Grains and tubers	2	0.8	259	92.2	14.578	4	0.056
Legumes and nuts	1	0.4	260	99.6			
Dairy products	0	0	261	100			
Flesh foods(Meat)	0	0	261	100			
Eggs	0	0	261	100			
Vitamin-Arich fruits & vegetables	0	0	261	100			
Other fruits &vegetables	0	0	261	100			
	WAZ<-2SD		WAZ≥-2SD				
Grains and tubers	9	3.4	252	96.6	9.145	4	0.147
Legumes and nuts	5	1.9	256	98.1			
Dairy products	2	0.8	259	99.2			
Flesh foods(Meat)	0	0	261	100			
Eggs	1	0.3	260	99.7			
Vitamin -A fruits & vegetables	0	0	261	100			
Other fruits & vegetables	0	0	261	100			
	HAZ<-2SD		HAZ≥-2SD				
Grains and tubers	14	5.4	247	94.6	3.255	4	0.789
Legumes and nuts	11	4.2	250	95.8			
Dairy products	5	1.9	256	98.1			
Flesh foods(Meat)	1	0.4	260	99.6			
Eggs	1	0.4	260	99.6			
Vitamin-A rich fruits & vegetables	1	0.4	260	99.6			
Other fruits &vegetables	2	0.8	259	99.2			

Source; (Research Findings, 2019)

Key: WHZ=Weight for Height Z-scores, WAZ= Weight for Age Z-scores, HAZ= Height for Age Z-scores

ii. *Association of monthly incomes factors on the nutritional status of children aged 6-59 months attending baby well clinic at Ekerenyo sub county hospital*

A total of 261 caregivers of children were interviewed on their monthly incomes to establish association with malnutrition status of children aged between 6-59 months. The caregivers within the low income bracket earning less than Kes. 3,000 was statistically significant associated with malnutrition status of children as depicted with wasting ($\chi 2$ =18.677, p-value=0.007), underweight ($\chi 2$ =16.345, p-value=0.011) and stunting ($\chi 2$ =13.239, p-value=0.016). The table 4.6 below illustrated the findings in details.

Table 4.6: Association of monthly income factors on the nutritional status of children aged 6-59 months attending baby well clinic at Ekerenyo sub county hospital

Variable	WHZ<-2SD		WHZ≥-2SD		χ2	Df	p-value
	n	%	n	%			
Monthly Income in Kes. (N=261)							
Less than 3000	2	2.9	58	97.1	18.677	3	0.007
3,000-10,000	1	1.5	64	98.5			
10,000-15,000	0	0	60	100			
15,000-20,000	0	0	39	100			
20,000-30,000	0	0	28	100			
	WAZ<-2SD		WAZ≥-2SD				
Less than 3,000	9	13.0	60	87	16.345	3	0.011
3,000-10,000	4	6.2	61	93.8			
10,000-15,000	2	3.3	58	96.7			
15,000-20,000	1	2.6	38	97.4			
20,000-30,000	1	3.6	27	96.4			
	HAZ<-2SD		HAZ≥-2SD				
Less than 3,000	17	24.6	43	75.4	13.239	3	0.016
3,000-10,000	11	16.9	54	83.1			
10,000-15,000	4	6.7	65	93.3			
15,000-20,000	2	5.1	37	94.9			
20,000-30,000	1	3.6	27	96.4			

Source; (Research Findings, 2019)
Key: WHZ=Weight for Height Z-scores, WAZ= Weight for Age Z-scores, HAZ= Height for Age Z-scores

V. Conclusion and Recommendations

a) Conclusion

Malnutrition prevalence remains an alarming issue in the country. It merges that nearly half of all deaths in children under 5 are attributable to malnutrition; malnutrition puts children at greater risk of dying from common infections, increases the frequency and severity of such infections, and delays recovery. The interaction between malnutrition and infection can create a potentially lethal cycle of worsening illness and deteriorating nutritional status. Poor nutrition in the first 1,000 days of a child's life can also lead to stunted growth, which is associated with impaired cognitive ability and reduced school and work performance.

The findings of the study established that wasting (WHZ<-2SD) was 1.2% with 0.4% severely wasted. The proportion of children who were underweight (WAZ<-2SD) was 6.5% of whom 1.1% were severely underweight. Stunting (HAZ<-2SD) was 13.4% with 1.5% severely wasted. The effect of wasting associated with malnutrition was significant (χ2 12.543, p-value =0.013) and underweight (χ2 10.143, p-value =0.026). The effect of stunting with malnutrition was slightly significant (χ2 8.223, p-value =0.056). Scientific evidence has shown that beyond the age of 6-59 months the effects of chronic malnutrition are irreversible. This means that to break the intergenerational transmission of poverty and malnutrition, children at risk must be reached during their first two years of life. Child malnutrition is the single biggest contributor to under-five mortality due to greater susceptibility to infections and slow recovery from illness.

b) Recommendations

Providing adequate food to meet the nutritional needs of growing children is critical to prevent an increase in malnutrition prevalence, which would lead to excess mortality during the recovery phase of the condition. Malnourished children are particularly vulnerable, as they cannot develop the protective compensatory mechanisms that allow healthy individuals to survive during periods of food deprivation. On the other hand, good nutritional status promotes wound healing and improves the postnatal outcomes in both mothers and babies. According to the World Health Organization (WHO), "food security exists when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences, and to maintain an active and healthy life. Adequate nutrition is vital to everyone's health and well-being. Even in the best of times there are multiple challenges to proper nutrition. The study recommends the following;

i. There should be intersect oral collaboration among stakeholders to work together to strengthen nutritional services.
ii. To achieve optimal results, participation and involvement of mothers and other community stakeholders should be established or strengthened towards addressing child malnutrition.

iii. There should be provision of essential services and increasing access to healthcare to reduce burden of diseases, which increase vulnerability to diseases.
iv. The community members' capacity on balanced diet should be enhanced; they should take a balanced diet.

References Références Referencias

1. Abubakar, A.; Holding, P.; Mwangome, M. & Maitland, K. (2011). *Maternal Perceptions of Factors Contributing to Severe Under-Nutrition among Children in a Rural African Setting. Rural Remote Health,* 11: 1423.
2. Adeba, E. (2014). Prevalence of Chronic Malnutrition (Stunting) and Determinant Factors among Children Aged 0-23 Months in Western Ethiopia: A Cross *Sectional Study. J Nutr Disorders Ther* 4: 23.
3. Ayieko, M.A. & Midika, K.F. (2010). Seasonality of *Food* Supply, Coping Strategies and Child Nutritional Outcomeln Sabatia-Kenya. *Adv J Food Scitechnol* 2: 279-285.
4. Armstrong, J.; Dorosty, A. R.; Reilly, J. J.; Emmett, P. M. (2003). *Child Health Information Team Coexistence of Social Inequalities in Undernutrition and Obesity in preschool Children: Population Based Cross Sectional Study.* Arch Dis Child, 88: 671-675.
5. Blössner, E.; Borghi, R.; Morris, & Frongillo, E. A. (2004). "Methodology for Estimating Regional and Global Trends of Child Malnutrition." *International Journal of Epidemiology*, 33 (6): 1260-70
6. Blössner, M. & Onis, M. (2005). *Malnutrition: Quantifying the Health Impact at National and Local Levels*. WHO Environmental Burden of Disease Series, 12. Geneva: WHO.
7. Black, R. E.; Allen, L. H.; Bhutta, Z. A.; Caulfield, L. E. & de Onis, M. *et al.,* (2008). *Maternal and Child Undernutrition: Global and Regional Exposures And Health Consequences.* Lancet 371: 243-260.
8. Bhattacharya, J.; Currie, J. & Haider, S. (2004). Poverty, Food Insecurity, and nutritional Outcomes in Children and Adults. *J. Health Econ* 23: 839-862.
9. Bhutta, Z. A.; Das, J. K.; Rizvi, A.; Gaffey, M. F. & Walker, N. *Et Al.,* (2013). *Evidence-Based Interventions for Improvement of Maternal and Child Nutrition:* What Can Be Done and at what cost? Lancet, 382: 452-477.
10. Black, R. E.; Victora, C. G.; Walker, S. P.; Bhutta, Z. A. & Christian, P. *et al.,* (2013). *Maternal and Child Undernutrition and Overweight in Low-Income and Middle-Income Countries.* Lancet, 382: 427-451.
11. Central Statistical Agency (2013). *Ethiopia 201DHS.* Stud Fam Plann 44: 233-242.
12. Coates, J.; Swindale, A. & Bilinsky, P. (2007). *Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access*: Indicator Guide. Washington DC: Food and Nutrition Technical, USA.
13. Duran, P.; Caballero, B. & de Onis, M. (2006). *The Association between Stunting and Overweight in Latin American and Caribbean Preschool Children*. Food Nutr. Bull 27: 300-305.
14. Dorresteijn, W. (2011). *Community Development in the Policy Arena*. KirindonCommunity Development Report.
15. Gwatkin, D. R. (2000). *Health Inequalities and the Health of the Poor: What do we know? What can we do? Bull World Health Organ 78: 3-18.*
16. Jones-Smith, J. C.; Gordon-Larsen, P.; Siddiqi, A. & Popkin, B.M. (2008). Is The Burden of overweight shifting to the poor across the globe? time trends among womenin 39 Low- and Middle-Income Countries (1991-2008). *Int J Obes* (Lond) 36: 1114-1120.
17. Haddad L, Achadi E, Bendech MA, Ahuja A, Bhatia K, et al. (2015) The Global Nutrition Report 2014: Actions and Accountability to Accelerate the World's Progress on Nutrition. *J Nutr* 145: 663-671.
18. Hoddinatt, J.; Rosegran, M. & Torero, M. (2012). Hunger and Malnutrition: Investments to Reduce Hunger and Under-Nutrition, Paper Prepared for 2012 Global Copenhagen Consensus, *International Food Policy Research Institute,* Washington, DC.
19. Kanjilal, B.; Mazumdar, P. G.; Mukherjee, M. & Rahman, M.H. (2010). *Nutritional Status* of Children in India: Household Socio-Economic Condition as the contextual Determinant. *Int. J Equity Health* 9: 19.
20. Kramer, M. S. (2003). *The Epidemiology of Adverse Pregnancy Outcomes*: An overview. *JNutr,* 133: 1592s-1596.
21. Kimani-Murage, E. W.; Muthuri, S. K.; Oti, S.O.; Mutua, M. K.; van de Vijver, S. *et al.,* (2015). *Evidence of a Double Burden of Malnutrition in Urban Poor Settings in Nairobi, Kenya.* PLoS One 10: e0129943.
22. Martorell, R.; Young, M. F. (2012). *Patterns of Stunting and Wasting*: *Potential Explanatory Factors. Adv. Nutr 3: 227-233.*
23. Matanda, D. J.; Mittelmark, M. B.; Kigaru, D. M. (2014). *Child Undernutrition in Kenya:* Trend Analyses from 1993 To 2008-09. Bmc Pediatr 14: 5.
24. Muhimbula, H. S.; Issa-zacharia, A. (2010). Persistent Child Malnutrition in Tanzania: Risks Associated with Traditional Complementary Foods (A Review). *Afr J Food Sci* 4: 679-692.
25. Martorell, R.; Kettel Khan, L.; Hughes, M. L. & Grummer-Strawn, L. M. (2000). Overweight and Obesity in Preschool Children from Developing Countries. *Int J Obes Relat Metab Disord*, 24: 959-967.

26. Moore, S. (2001). Early Children Diarrhea and Helminthiases Associated with Long Term Linear Growth Faltering. *International Journal of Epidemiology*, 30 (3), 1457-1464.
27. Mugenda, M. O. & Mugenda, G. A. (1999). *Research Methods: Quantitative and Qualitative Approaches*. ACTS Press, Nairobi, Kenya.
28. Muthuri, S. K.; Francis, C. E.; Wachira, L. J.; Leblanc, A. G. & Sampson, M, *et al.,* (2014). *Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa:* A Systematic Review. Plos One 9: E92846.
29. Ortiz, J.; Van Camp, J.; Wijaya, S.; Donoso, S. & Huybregts, L. (2014). *Determinants of Child Malnutrition in Rural and Urban Ecuadorian Highlands.* Public Health Nutr.17: 2122-2130.
30. Reilly, J .J. & Kelly, J. (2011). Long-Term Impact of Overweight and Obesity in Childhood and Adolescence on Morbidity and Premature Mortality in Adulthood: Systematic Review. *Int J. Obes* (Lond) 35: 891-898.
31. Rytter, M. J. H.; Kolte, L.; Briend, A.; Friis, H. & Christensen, V.B. (2014). *The Immune System in Children with Malnutrition -A Systematic Review.* PLoS One, 9(8).https://doi.org/10.1371/journal.pone.0105017
32. UNICEF; WHO & the World Bank (2012). *Joint Child Malnutrition Estimates*: *Levels & Trends in Child Malnutrition,* Africa.
33. UNICEF & Bank, W. T. W. (2014). *Levels and Trends in Child Malnutrition. Midwifery,* 4. https://doi.org/10.1016/S0266-6138(96)90067-4.
34. UNICEF & WHO (2015). *Levels & Trends in Child Mortality.* Report 2015, 1–34.
35. UNICEF; World Health Organization & the World Bank (2012). *UNICEF-WHO- World Bank. Joint Child Malnutrition Estimates*: *Levels & Trends in Child Malnutrition. Africa,* 35. https://doi.org/10.1093/ije/dyr050 Vorster, H. (Esté) H. (2010).
36. United Nations Children's Fund. Annual Results Report (2015). *Nutrition. New York: UNICEF; [Cited 2017 May 21].* Available from: http://www.Unicef.org/publicpartnerships/files/2015ARR_Nutrition.pdf
37. Varadharajan, K. S.; Thomas, T.; Rajaraman, D.; Kurpad, A.V. & Vaz, M. (2013). Overweight and Obesity among Internal Migrants in India. *Asia Pac J Clin. Nutr. 22*: 416-425.
38. Skalicky, A.; Meyers, A. F.; Adams, W. G.; Yang, Z. & Cook, J.T. *et al.,* (2006). Child Food Insecurity and Iron Deficiency Anemia in Low-Income Infants and Toddlers in the United States. *Matern Child Health J.* 10: 177-185.
39. Krejcie, R. V. & Morgan, D. W. (1970). *Determining Sample Size for Research Activities*. Education and Psychological Measurement, 30, 607-610.
40. Kimani-Murage, E. W.; Madise, N. J.; Fotso, J. C.; Kyobutungi, C. & Mutua, M. K. *et al.,*(2011). *Patterns and Determinants of Breastfeeding and Complementary Feeding Practices in Urban Informal Settlements,* Nairobi Kenya. Bmc Public Health 1: 396.
41. Martorell, R. (2001). Is Wasting (Thinness) a Hidden Problem in Latin America's Children? *J Nutr.* 131: 1133-1134.
42. Popkin, B. M. (2002). Part II. *What is Unique about the Experience in lower-and Middle-Income Less-Industrialized Countries Compared With The Very-High Income Industrialized Countries*? Public Health Nutrition 5: 205-214.
43. Pathak, P. K. & Singh, A. (2011). Trends in Malnutrition among Children in India: Growing Ineaqualities. *J. Soc Sci Med* 73: 576-585.
44. Pelletier, D. L.; FrongilloJr, E. A.; Schroeder, D. G. & Habicht, J. P. (1995). *The Effects of Malnutrition on Child Mortality in Developing Countries*. Bulletin of the World Health Organization, 73 (4), 443.
45. Shinsugi, C.; Matsumura, M.; Karama, M.; Tanaka, J.; Changoma, M. *et al.,* (2015) *Factors Associated With Stunting Among Children According To The Level of Food Insecurity in the Household:* A Cross-Sectional Study in a Rural Community of Southeastern Kenya. BMC Public Health 15: 441.
46. Stephenson, L. & Ottesen, E. (2008).Malnutrition and Parasitic Helminthes Infections Parasitology, *Scientific World Journal,* 121 (23), 523-538.
47. Tzioumis, E. & Adair, L. S. (2014). *Childhood Dual Burden of Under- and Overnutrition in Low- and Middle-Income Countries*: A Critical Review. Food Nutr Bull 35: 230243.
48. UNIGME (2013). *Levels and Trends in Child Mortality Report 2013*.
49. Van de Poel, E.; Hosseinpoor, A. R.; Jehu-Appiah, C.; Vega, J.; Speybroeck, N. (2007). Malnutrition and the Disproportional Burden on the Poor: The Case of Ghana. *Int.J. Equity Health* 6: 21.
50. WHO; UNICEF; UNFPA & World Bank (2012). *The World Trends in Maternal Mortality*: 1990 to 2010. World Health Organization, Geneva, Switzerland.
51. WHO (2012). *Trends in Maternal Mortality:* 1990 to 2010. WHI, UNICEF and the World Bank Estimates.
52. WHO (2006). *WHO Child Growth Standards Length/Height for Age, Weight for Age, Weight for Length or Height and Body Mass Index for Age Methods of Development*. WHO. Geneva. Pg. 43.

Global Journal of Medical Research: L
Nutrition & Food Science
Volume 21 Issue 1 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

Microbial Load of Sliced and Unsliced Commercialized Indigenous Vegetable; *Gnetum Africanum* in Abia State, Nigeria

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Abstract- This study investigated the microbial activity present in sliced and unsliced commercialized leaves of Gnetum africanum in the humid region of Abia State, Nigeria. This indigenous vegetable contains nutrients that encourage microbial growth, which if not properly handled in a hygiene environment may lead to proliferation of microorganisms. One hundred grams each of sliced and unsliced leaves of Gnetum africanum were obtained randomly from three different markets, these samples were homogenized in distilled water and analysis was carried out following standard microbiological methods. Predominant isolates present were Bacillus cereus, Staphylococcus aureus, Leuconostoc spp, Streptococcus spp and Aspergillus brasilensis. The results from this study showed that the sliced leaves purchased from market B had the highest total viable count for bacteria (2.58 × 106 cfu/g) and the least bacteria count was observed in market C (1.94 × 104 cfu/g).

Keywords: *gnetum africanum, indigenous vegetable, microbial load, bacteria count.*

GJMR-L Classification: *NLMC Code: QW 51*

Strictly as per the compliance and regulations of:

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Abstract- This study investigated the microbial activity present in sliced and unsliced commercialized leaves of *Gnetum africanum* in the humid region of Abia State, Nigeria. This indigenous vegetable contains nutrients that encourage microbial growth, which if not properly handled in a hygiene environment may lead to proliferation of microorganisms. One hundred grams each of sliced and unsliced leaves of *Gnetum africanum* were obtained randomly from three different markets, these samples were homogenized in distilled water and analysis was carried out following standard microbiological methods. Predominant isolates present were *Bacillus cereus, Staphylococcus aureus, Leuconostoc spp, Streptococcus spp and Aspergillus brasilensis*. The results from this study showed that the sliced leaves purchased from market B had the highest total viable count for bacteria (2.58×10^6 cfu/g) and the least bacteria count was observed in market C (1.94×10^4 cfu/g). This same trend was observed in the unsliced commercialized leaves of *Gnetum africanum*. Furthermore, out of the six isolates identified, *Bacillus cereus* had the highest frequency of 36.4% followed by *Staphylococcus aureus* with a frequency of 27.27 % while the lowest frequency was observed with *Pseudomonas aeruginosa* (2%). The commercialized vegetable may have been contaminated by these bacteria through improper handling techniques by the traders such as bags or baskets which were used to convey and cover the leaves from one place to another, insects, equipment's and the environment. Thus, the need should be emphasized for proper cleaning of the materials before and after use. Also, awareness on personal hygiene and food safety should also be strongly encouraged in the rural communities as the continuous ingestion of these organisms in large numbers, could probably lead to gastrointestinal illness especially amongst the vulnerable citizen such as those suffering from terminal diseases, the infants and the aged with weak immune competence.

Keywords: gnetum africanum, indigenous vegetable, microbial load, bacteria count.

I. Introduction

Vegetables are an integral component of our daily diets (Bassey *et al*., 2015) and forms important condiment in our daily foods especially in the rural areas of Nigeria where carbohydrates are mainly consumed. These indigenous leafy vegetables are important sources of protective foods (Nnamani, *et al*., 2009), they play useful role in digestion and also provides proteins, minerals, vitamins and fats (Onyeagocha, 1995). They have been reported to be good sources of minerals as well as vitamins (Adenipenkun and Oyetunji, 2010).

One of such vegetables is *Gnetum africanum. Gnetum africanum* Welw. is a shade-loving dioecious evergreen perennial liana, it grows extensively in the rainforest zone in South Eastern Nigeria. This vegetable is widely consumed by almost every household because of its dietary importance, palatability and taste. It belongs to the family of Gnetaceae and it is commonly known as "Eru" in English, "Afang or Okazi" in Nigeria, "Eru or Kok" in Cameroon, "Koko" in the Republic of Central Africa, "Ntoumou" in Gabon. Its uses for medicinal and nutritional value have been supported by several authors (Schippers, 2004; Schippers and Besong, 2004: Abia *et al*., 2007). It is eaten as a vegetable salad and in the preparation of afang soup (Domenyang *et al*., 2001). Medically the leaf is used to treat nausea and is considered as an antidote to some form of poison. According to Winston Craig (2017), the species are useful in reducing the risk of cancer and heart disease since they are low in fat, high in dietary fiber and rich in folic acid and vitamin C.

Gnetum africanum is mostly sold at farm gate and markets especially those situated in the rural areas where minimal or no attention to environmental sanitation and hygiene is observed. This could result to an outbreak of food borne epidemic, such as gastroenteritis and other seeming stomach upset, especially in rural settings where there is minimal access to functional health system (Azuonwu *et al*., 2016). According to Azuonwu *et al*. (2019) the level of hygiene outcome in the market, revealed that traders are chiefly concerned on maximizing profit rather than proper cleaning of their environment and materials used in selling their products. This would likely promote the presence and proliferation of microorganisms and subsequent transfer to the products being sold. Eni *et al*. (2010) buttressed further on the contamination of leaves by microorganisms which may occur through direct contact with soil, dust, water and by handling at harvest or during postharvest processing. These spoilage microorganisms are capable of colonizing and

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creating lesions on healthy, undamaged plant tissue (Miedes and Lorences, 2004). Howbeit, the reoccurring practice of the traders provides conducive media for the growth of microorganisms, possibly pathogenic ones to thrive. Hence, the data obtained from this market-based research would provide information for the policy/decision makers and health officers on possible ways to educate and inform the rural settings and markets on the importance of personal hygiene. This can be achieved by organizing workshops at the village level, jingles on radio as this will promote safety in food, since the leaves are eaten mostly in its raw state. Thus, the understanding of the microbial load present in sliced and unsliced commercialized leaves of *Gnetum africanum* is important with a view to isolate and identify the microorganisms present and its causative effect on human.

II. Materials and Methods

a) Study Area

This study was carried out in three major markets in three Local Government Areas (LGAs), namely; Ikwuano, Umuahia South and Ukwa west LGAs in Abia State, Nigeria. These LGAs where the markets are located lies between latitude 5° 26[1] N and longitude 7°34[l] E characterized with an average rainfall of 2351mm, average minimum temperature of 22.9°C and a relative humidity range between 80 – 89%.

b) Sample Collection/Research Design

A total of 100 g each of sliced and unsliced samples of *Gnetum africanum* were randomly purchased from traders in three markets namely Ndioru market in Ikwuano LGA, Apumiri market in Umuahia South and Ahia afor market in Ukwa west LGA, Abia State, Nigeria. The samples were collected aseptically with sterile gloves and transported in sterile polyethylene bags and microbiologically analyzed at the New Covenant Laboratory Aba, Abia State, Nigeria.

III. Microbiological Analysis

a) Sample Preparation

The media used were peptone water, Macconkey agar, blood agar for the bacteriological study, while Sabouraud dextrose agar (SDA) was used to detect the fungi present in the sample and the preparation was carried out according to manufacturer's specification.

b) Isolation of microorganisms

Known sample weight (1 g) of sliced and unsliced leaves of *Gnetum africanum* were dispensed into 9 ml of sterile distilled water each and stirred with sterile spatula. Thereafter, serial dilution was carried out up to 10^4.

A homogenate aliquot of the serially diluted sample (0.1 ml) was inoculated onto already prepared and cooled Nutrient agar, Macconkey agar, blood agar and Sabouraud dextrose agar (SDA using spread plate method. The plates were incubated at 37°C for 24 hours for the isolation of bacteria while saboraud dextrose agar (SDA) was incubated at room temperature (28±2°C) for 3 to 5 days for the isolation of fungi. After 24 hours the Macconkay and blood agar plates were observed for bacterial growth.

c) Identification of bacterial isolates

Colonies were isolated and purified and subjected to Gram staining and biochemical tests. The fungal isolate was purified and observed both macroscopically and microscopically according to Watanabe (2010); Xu *et al*., (2015).

IV. Results and Discussion

Commercialized leaves of *Gnetum africanum* both sliced and unsliced were randomly purchased from traders in three major markets located in three LGAs in Abia State, Nigeria.

The bacteriological analysis revealed that the sliced leaves purchased from market B had the highest bacterial count of 2.58×10^6 cfu/g compared with the value obtained from market A(2.01×10^5 cfu/g), followed by market C(1.94×10^4) (Table1), this same order (B>A>C) was observed in the unsliced commercialized leaves of *Gnetum africanum*.

Table 1: Total Viable count (cfu/g) Bacteria

Sample	Total Viable count (cfu/g)		
	A	B	C
Unsliced *Gnetum africanum*	$1.78\times10^3\pm0.20$	$1.83\times10^4\pm0.24$	$1.69\times10^2\pm0.42$
Sliced *Gnetum africanum*	$2.01\times10^5\pm0.12$	$2.58\times10^6\pm0.32$	$1.94\times10^4\pm0.41$

**** A=Ndioru market, B=Apumiri market, C=Ahia Afor market*
Results are mean ± SD of triplicate determinations

The high bacterial population in the leaves of *Gnetum africanum* could be caused by the unhygienic environment where the leaves are sold coupled with the fact that the trays, chopping board and knives are constantly exposed, and also the use of waste water for manure. This finding corroborates Mritunjay and Kumar (2015) who stated that pre- and/or post-harvest contamination could lead to build up of organisms. Lam *et al.* (2015) reported that the use of wastewater excreta in agriculture may put communities at risk especially when contaminated fruits and vegetables are consumed raw. *Staphylococcus aureus* which was the 2nd prevalent bacteria in the sample analyzed is a common microflora on human skin (Ajayi *et al*., 2017). Therefore, the commercialized vegetable may have been contaminated through improper handling techniques by the traders, bags or basket (used to convey and cover

the leaves from one place to another, insects, equipment's and the surrounding environment.

The study also revealed that out of the six isolates, *Bacillus cereus* had the highest frequency with a percentage occurrence of 36.4 % followed by *Staphylococcus aureus* with a percentage of occurrence of 27.27 % while the lowest frequency (2 %) was observed with *Pseudomonas aeruginosa* as depicted in Table 2. *Bacillus cereus* is of vegetable origin and normally found in the soil (Azuonwu *et al.,* 2019), this bacterium can be classified as a normal microflora on plant surfaces (Barth *et al.,* 2009). *Bacillus cereus* is a common environmental contaminant with its cells creating spores, these cells have the ability to produce extracellular lytic enzymes such as cellulase, hemicellulase, lignocellulase and pectinase (Barth *et al*., 2009) which are associated with food spoilage. This organism is able to form heat-resistant spores in the soil (their natural habitat); hence, the contamination of food with sand or dust blown up by air current may probably be one of the ways of introducing the pathogen on the food stuffs (Azuonwu *et al.,* 2019). Also, the presence of these microorganisms in the leaves especially sliced *Gnetum africanum* may have occurred due to a large surface area as a result of slicing and exposing the leaves to microorganisms during pre/post-harvest or during storage, as was also observed by Bhat *et al*. (2010). This finding was also buttressed further by Dinges *et al*. (2000) who opined that the presence of *Staphylococcus aureus* and *Bacillus* specie are potential risk, because these organisms are able to produce toxins which are harmful to humans when ingested. The ingestion of these organisms in large numbers, probably above 100 cfu /ml could probably lead to gastrointestinal illness, though the degree and critical nature of the infection in an individual may differ, based on individual specific immune response capacity especially those who are suffering from terminal diseases, the infants and the aged with weak immune competence (Azuonwu *et al*., 2019).

Table 2: Frequency of isolated bacteria found in Gnetum africanum leaves

Isolated organism	Sample	
	Freq.	%tage
Bacillus cereus	16	36.36
Staphylococcus aureus	12	27.27
Leuconostoc spp	9	20.46
Streptococcus spp	5	11.37
Escherichia coli	Nil	nil
Pseudomonas aeruginosa	2	4.54
Total	44	100

In the three markets where samples were purchased, *Bacillus cereus* and *Staphylococcus aureus* were present in both sliced and unsliced commercialized leaves of *Gnetum africanum*. *Leuconostoc spp* was also present in all the analyzed market samples except from the sample purchased from Market C. *Pseudomonas aeruginosa* was only present in sliced leaves purchased from Market A and B (Table 3). It is worth noting that using blood agar as a medium, *Streptococcus spp* was present in the sliced leaves of commercialized *Gnetum africanum* purchased from Market B and C and the unsliced leave of market B. *Escherichia coli* was absent in all the samples (Table 3). Mgbakogu and Eledo (2015) opined that *Bacillus cereus* causes a toxin medicated disease rather than infection which includes illnesses like vomiting, abdominal cramps and watery diarrhea. Thus, the presence of this organism is consistent with potential health hazards. *Staphylococcus aureus* is considered as one of the most important bacteria that causes diseases in humans such as abscesses (boils). *Pseudomonas aeruginosa* on the other hand is prevalent among patients with wounds, burns, and some blood stream infections. *Leuconostoc spp* are beneficial bacteria which are capable of causing rare infections in humans.

Table 3: Presence of bacteria in the sliced and unsliced *Gnetum africanum* leaves

Bacteria Isolates	Unsliced leaves			Sliced leaves		
	A	B	C	A	B	C
Bacillus cereus	+	+	+	+	+	+
Staphylococcus aureus	+	+	+	+	+	+
Leuconostoc spp	+	+	+	+	+	_
Streptococcus spp	-	+	-	-	+	+
Escherichia coli	-	-	-	-	-	-
Pseudomonas aeruginosa	-	-	-	+	+	-

KEY: A = Ndioru market, B= Apumiri market' C= Ahia Afor market + =Present, - +Absent

Furthermore, result from the fungal analysis revealed that only one fungus named *Aspergillus brasiliensis* formerly known as *Aspergillus niger* was the predominant fungus observed in the sliced leaves of commercialized *Gnetum africanum*. This implies that the level of fungi on *G. africanum* is minimal compared to bacteria. This finding is in consonance with Oranusi, *et al.* (2020), the author observed that *A. niger* had the highest occurrence (73.33%) in the samples analyzed. This fungus is commonly found in plant and affects the health of humans such as hearing loss and lungs infection. This finding is in agreement with that of Josia *et al.* (2015), whose study observed that most fruits and vegetables consumed in the eastern part of Nigeria are grossly contaminated with microorganisms that are involved in food borne disease.

Thus, most of the reported isolates from this study were bacteria, which were prevalent both in the sliced and the unsliced leaves of commercialized *Gnetum africanum*. This establishes the fact that bacteria were a dominant causative spoilage agent.

However, the importance of the provision of potable water in all the nook and cranny of our local markets by government and her agencies cannot be over emphasized. It is probably believed that non-provision of potable sources of water, which should be accessible regularly for washing and keeping the environment clean may likely promote these public health issues in our local markets, thus the public health implication of such practice is very massive, as cases of gastroenteritis and diarrhea will be highly prominent in the area. This is a great public health concern and potential health risk that calls for urgent attention.

V. Conclusion

This study has presented the microbial load of *Gnetum africanum*. Some pathogenic microorganisms were isolated suggesting a public health risk as the bowl, knives and chopping boards are often used and re-used without sanitization. *Bacillus cereus, Staphylococcus aureus, Leuconostoc spp, Streptococcus spp and Pseudomonas aeruginosa* were among the isolated bacteria with *Bacillus cereus* having the highest percentage occurrence. The products are cheap but can be detrimental to health because consumers are increasingly unaware of the dangers of microbial load present on the leaves of *Gnetum africanum*. Individuals, companies and households using *Gnetum africanum* should always wash and cook properly before eating to avoid health problems.

References Références Referencias

1. Abia, W., Numfor, F., Wanji, S. and Tcheuntue, F. (2007). "Energy and nutrient contents of
2. "waterfufu and *Gnetum*"." *African Journal of Food Science* October: 016-019.
3. Adenipenkun, C. O., Oyetunji, O. J. (2010). Nutritional values of some tropical vegetables. *J Appl Biosci*; 35: 2294-2300.
4. Ajayi A. A., Bibi O., Oniha M. I., Atolagbe O. M., Anosike S. O., Onibokun E. A. (2017): Studies on *Staphylococcus aureus* isolated from pimples. *Pakistan Journal of Biological Sciences*, 20: 350–354.
5. Azuonwu, O., Azuonwu, T. C., Ndah, M. A. (2019). Isolation and identification of potential high-risk pathogens from blenders used in grinding some food stuffs in a local community market in rivers state: a public health concern. *J Microbiol Exp.*; 7(4):183–187. DOI: 10.15406/jmen.,.07.00258
6. Azuonwu, O., Nnenna, I., Douglass, A. S., (2016). Consequences of Haemolytic Disease of the Fetus and Newborn (HDFN) and the Clinical Significance of Antibody Screening in Prenatal Diagnosis: A Study of Multigravidal and Primigravidal Women in Port Harcourt, Niger Delta. *Journal of Clinical Laboratory Medicine*. 1(1):1–7.
7. Barth, M., Thomas, R. H., Hong, Z., Frederick, B. (2009): Microbiological spoilage of fruits and vegetables. In: Sperber W.H., Doyle M.P. (eds): Compendium of the Microbiological Spoilage of Foods and Beverages: Food Microbiology and Food Safety. Springer Science+Business Media, Berlin: 135–183.
8. Bassey, N. E., Akpaeti, A. J., Okon, E. U. and Nyong, E. E. (2015). Determinants of Flutted Pumpkin (*Telferia occidentalis*) Production and Profitability in Akwa Ibom State, Nigeria. *American Journal of Experimental Agriculture,* 5(2): 109-117.
9. Bhat, R., Rai, R.V., Karmin, A. (2010): Mycotoxins in food and feed: present status and future concerns. Comprehensive Reviews in Food Science and Food Safety, 9: 57–81.
10. Dinges, M. M., Orwin, P. M., Schlievert, P. M. (2000). Exotoxins of *Staphylococcus aureus*. *Clin Microbiol Rev*. 13(1):16–34
11. Domenyang, P. F., John, C. A., Paul, D. F. (2001). Traditional medicines of Congo (Brazaville). Paris: ORSTOM; p. 114.
12. Eni, A. O., Oluwawemitan, I. A., Solomon, O. U. (2010): Microbial quality of fruits and vegetables sold in Sango Ota, Nigeria. *African Journal of Food Science*, 4: 291–296.
13. Josiah, A. Lennox, Matthew, E., Uwamere, E., Chinyere, O. and Okpako, E. C. (2015). Incidence of Salmonella and Shigella Species on some Selected Fruits and Vegetables Obtained from Open Area Markets in Calabar Metropolis. *Int. J. Curr. Microbiol. App. Sci* 4(5): 262-268
14. Lam, S., Nguyen-Viet, H., Tuyet-Hanh, T. T., Nguyen-Mai, H., Harper, S. (2015): Evidence for public health risks of wastewater and excreta management practices in Southeast Asia: a scoping review. *International Journal of Environmental Research and Public Health*, 12: 12863–12885.
15. Mgbakogu, R. A. and Eledo, B. O. (2015). Evaluation of Bacillus cereus contamination of local vegetables in Obori, Nigeria: *Journal of Biology, Agriculture and Healthcare*, 5(15):1-6.
16. Miedes, E., Lorences, E. P. (2004): Apple (*Malus domestica*) and tomato (*Lycopersicum esculentum*) fruits cell-wall hemicelluloses and xyloglucan degradation during *Penicillium expansum* infection. *Journal of Agricultural and Food Chemistry*, 52: 7 957–7 963.
17. Mritunjay S. K., Kumar V. (2015): Fresh farm produce as a source of pathogens: A review. *Research Journal of Environmental Toxicology*, 9: 59–70.

18. Nnamani, C. V., Oselebe, H. O., Agbatutu, A. (2009). Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State, Nigeria. *Afr J Biotechnol*; 8(9): 2321-2324.
19. Onyeogacha, C. Y., (1995). Qualitative estimation of dietary contribution of phytate, oxalate and hydrocyanate by six popular Nigeria food stuffs. *Nig. Nutri. Sci* 10:24-29.
20. Oranusi S., Onibokun A., Afolabi O., Okpalajiaku C., Seweje A., Olopade B., Obafemi Y. (2020): Chemical, microbial and antioxidant activity of *Cola lepidota* K. Schum fruits. *Czech J. Food Sci*., 38: 11–19.
21. Schippers, R. R. (2004). *Gnetum buchholzianum* Engl. *Wageningen, Netherlands.* G. J. H. D. Grubben, O. A., PROTA (Plant Resources of Tropical Africa/Ressources végétales de ‟Afrique tropicale).
22. Schippers, R. R. and Besong, M. T. (2004). *Gnetum africanum* Welw. *Wageningen, Netherlands*. G. J. H. D. Grubben, O. A., PROTA (Plant Resources of Tropical Africa/Ressources végétales de l‟Afrique tropicale).
23. Watanabe, T. (2010): Pictorial Atlas of Soil and Seed Fungi: Morphologies of Cultural Fungi and Key to Species, 3th Ed. CRC Press, Taylor & Francis Group, Boca Raton, FL, USA: 426.
24. Xu, A., Pahl, D. M., Buchanan, R. L., Micallef, S. (2015). Comparing the microbiological status of pre- and postharvest produce from small organic production. *Journal of Food Protection*, 78: 1072–1080.

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Global Journal of Medical Research: L
Nutrition & Food Science
Volume 21 Issue 1 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

The Effect of Rapid Detection Methods on the Minimization and Prevention of the Risk of Contamination with Aflatoxins in Peanut Products

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Abstract- The methods of analysis and control of aflatoxins in peanuts pursue three key objectives: prevent the entry of contaminated peanuts into ready-to-eat products where they are used as an ingredient; prevent and minimize the risk of cross-contamination from contaminated peanuts to fit-for-use raw materials; perform an appropriate incoming inspection through rapid analysis methods for real-time detection of the absence of or the degree of contamination with aflatoxins. The aim of this study was to analyze the effect of rapid detection methods on the minimization and prevention of the risk of contamination with aflatoxins during the incoming inspection in industries using peanut products in the composition of the finished products. The methods of detection of aflatoxins in peanut products are: Mass Spectrometry combined with High - Performance Liquid Chromatography (HPLC), the internal methodology VAL 92:2010 developed by an accredited laboratory and immunochromatographic rapid tests.

Keywords: mycotoxins, aflatoxins, cross-contamination.

GJMR-L Classification: NLMC Code: QU 145

Strictly as per the compliance and regulations of:

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Keywords: mycotoxins, aflatoxins, cross-contamination.

I. Introduction

Peanuts are the raw material for the production of peanut butter, paste and oil, which are used as ingredients in various finished products such as biscuits, wafers and other confectionery products (Singh & Singh, 1991). As a good source of protein, peanuts are part of the balanced diet of many consumers (King et al., 2008), but, unfortunately, they are highly susceptible to contamination by mycotoxins (Cotty & Jaime-Garcia, 2007). Their high nutritional value creates a favorable environment for developing and potential contamination by aflatoxins (De Oliveira & Corassin, 2014). Aflatoxins have been proven toxic and carcinogenic and likely to increase the frequency of mutations above the natural level (Creppy, 2002). In subtropical areas where temperatures and humidity are optimal for the growth of molds and the production of toxins (Gourama & Bullerman, 1995), such toxins contaminate the raw materials used in the production of cereal-based foods such as peanuts, rice, corn, etc. Aflatoxins can be effectively removed from the contaminated raw materials by physical, chemical and biological methods (Bata & Lásztity, 1999), each of which has its advantages and disadvantages. This requires taking effective control measures to reduce exposure (Goldblatt, 2012) and ensure compliance with the statutory requirements for the maximum level of aflatoxins in terms of food safety. The legal requirements for the maximum level for aflatoxins (aflatoxins B1, B2, G1, G2 and M1) are defined in Commission Regulation (EC) No. 1881/2006 (Commission Regulation (EC), 2006). The recommendation of the European Parliament is that the Regulation determines a level for aflatoxins in foodstuffs that is as low as reasonably achievable. The maximum levels are shown in Table 1.

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Table 1: Maximum levels for aflatoxins per Regulation (EC) No. 1881/2006.

Foodstuff	Maximum levels (µg/kg)		
	B1	Sum of B1, B2, G1 and G2	M1
Peanuts and other oilseeds to be subjected to sorting or other physical treatment, before human consumption or use as an ingredient in foodstuffs, with the exception of peanuts and other oilseeds to be subjected to grinding for the production of refined vegetable oil	8.0	15.0	-
Peanuts and other oilseeds and processed products thereof intended for direct human consumption or use as an ingredient in foodstuffs, with the exception of crude vegetable oils intended for refining and refined vegetable oils	2.0	4.0	-

To assist the competent authorities in the official control of aflatoxin contamination, a "Guidance document for competent authorities for the control of compliance with EU legislation on aflatoxins" has been elaborated. In recent years, the European Food Safety Authority (EFSA) has adopted and published several scientific opinions on aflatoxins:

- September 1994, on the toxicological safety of aflatoxins B1, B2, G1, G2 and M1 (EFSA Panel, 2013);
- February 2004, on aflatoxins B1 as undesirable substances in animal feed (EFSA Panel, 2004);
- January 2018, on the potential increase of consumer health risk by a possible increase of the maximum levels for 'aflatoxin total' from 4 to 10 µg/kg in peanuts and processed products thereof intended for direct human consumption or use as an ingredient in foodstuffs (EFSA Panel, 2018)

In recent years researchers have explored various methods for identification of aflatoxins in peanut products, with particular attention to the following critical factors for the reliability of the analysis: accuracy of the sampling methods, needed due to the heterogeneous distribution of aflatoxins in the peanut batches; the high quality of the analyses performed, and reliability of the results obtained by the different methods of analysis. The provisions relating to methods of sampling for mycotoxins, including aflatoxins, are laid down in Commission Regulation (EC) No. 401/2006.

The role of the rapid analysis methods during incoming inspection aimed at prevention and management of the risk of cross-contamination has not been sufficiently analyzed.

The aim of this study was to analyze the effect of rapid detection methods on the minimization and prevention of the risk of contamination with aflatoxins during an incoming inspection in industries using peanut products in the composition of the finished products.

II. Methods

Materials. To perform an analysis by the HPLC method, we tested three samples of peanuts of 500g each taken from batch C 23/0817 in an accredited laboratory. For the purposes of immunochromatographic rapid tests, we used six samples of peanuts of 500g each taken from batch C 23/0817.

Methods. Mass Spectrometry combined with High-Performance Liquid Chromatography (HPLC) was conducted in an accredited laboratory. A standardized method was implemented: based on the recommendations in ISO 16050:2003, an internal laboratory methodology VAL 92:2010 was developed to detect aflatoxins in cereals, nuts and derived products. The limit of quantification of aflatoxin B1 and aflatoxin total B1, B2, G1 and G2 was 8 µg/kg. Immunochromatographic rapid tests. The sample was taken by the established sampling techniques and an extraction solution was prepared from the homogenized and finely ground peanuts 50 ± 0.2 g and 100 mL solution of 70% methanol / 30% distilled water. After preparing the mixture, filtering was carried out, using 2 to 3 mL of the extract for analysis. Using a pipettor, we pipetted portions of the six solutions (200 µL) into six different vessels and put into the test strips for aflatoxins. After three minutes, the test strips were removed and the results were read by visual observation. Interpretation of results was made as follows: samples where the test strip showed two lines were reported as negative (less than 20 ppb aflatoxin) and samples where the test strip showed only one line was deemed positive (20 or more ppb aflatoxin). Where the visual check did not establish any line appearing in the control zone, the test was deemed invalid and re-testing was made with another test strip.

III. Results and Discussion

Several factors for aflatoxin contamination have been identified. The factor with the greatest weight is contamination occurring before harvest (Parmar et al.,

1997). The treatment of peanuts reduces the formation of aflatoxins (Torres et al., 2014; Dorner, 2008) and the need for further corrective action. Although treatment is not always possible, prevention of contamination is the most effective method to combat all contaminants in foodstuffs. Upon receipt in the confectionery factory, peanuts must be checked under the procedures for incoming inspection. The recommended practice at this stage is to establish through documents control the origin of each batch of peanuts. Before performing an incoming inspection, it is necessary to establish that good hygiene practices were followed, especially during transportation, where contamination also can take place. The criteria for incoming inspection should be laid down in the specifications coordinated with the manufacturer of peanuts and peanut products intended for processing and use in the product. The specifications should include the maximum levels for aflatoxins and the respective methods and procedures of analysis and sampling. During the incoming inspection, it must be established that the supplied peanuts have no visible signs of deterioration; they are not musty or moldy and have not been infested by insects or rodents. The development of visible must or presence of mold eliminates the need for further analysis – the received batch must be isolated and rejected.

Under the existing legislation on food safety, food manufacturers must carry out control of all raw materials and ingredients under "Steps prior to hazard analysis" of the HACCP plan. The control of incoming raw materials should be documented in an Incoming Inspection Record. Raw materials must be inspected by personnel trained for carrying out such inspections.

The preliminary control should include:

- Control for a sanitary condition of the vehicle used to supply the raw materials;
- Check the integrity of the packaging of the raw materials;
- Check for visible signs of pest infestation;
- Check the accompanying documents, establishing the date of manufacture, batch date and the minimum durability period or best before date;
- Check the temperature conditions during delivery, if the raw materials are supplied under controlled conditions, where relevant.
- Check that the raw materials comply with the agreed specification for delivery.
- Check the condition of the used for loading and transportation of the raw materials.

The first stage of control of the supplied raw materials should include:

- Check that the quantity supplied corresponds to that indicated in the accompanying documents and agreed in contracts with the supplier;
- Documents control for compliance with what is indicated in the certificates of quality and safety of the shipment, including control of the origin of the raw material;
- Financial control for compliance of the price indicated in the accompanying documents with the agreed price of delivery;
- Control of the labeling and marking of the supplied raw material, to establish compliance with the contractual specification for the type of product, ingredients, storage conditions under temperature control, indications for specific uses.

The second stage of control includes carrying out laboratory tests. At this stage, the necessary analysis is conducted by microbiological and Physico-chemical indicators. The high risk of food contamination with mycotoxins requires an analysis to confirm the absence of aflatoxins in the supplied peanuts and peanut products. During the sampling for analysis, it should be borne in mind that the extreme heterogeneity of the possible contamination of peanuts with aflatoxins often leads to two types of errors. If the sample is smaller than the regulatory framework requires, this can lead to false-positive results for mycotoxins and cause usable peanuts to be destroyed. There is also a second group of errors related to the occurrence of false - negative results for contaminated batches, which the laboratory testing designates as compliant. To avoid these types of errors, the sampling procedures should be followed very accurately, which is not always possible due to the lack of highly qualified personnel in production companies engaged in carrying out analyses. In addition, the sampling for analysis should also be in line with several economic factors related to the limited budget of the mycotoxin testing program, including the cost of sampling and sample preparation, cost of analysis and cost of sending the samples to an accredited laboratory where the actual analysis will be performed.

It has been established that the most effective method for the quantitative determination of mycotoxins is high - performance liquid chromatography with mass spectroscopy, by which it is possible to simultaneously detect several types of mycotoxins in one sample. Although this method has its undeniable advantages and provides high precision, reliability and reproducibility of the results obtained, its application during incoming inspection of raw materials is extremely limited. Its shortcomings include high costs for carrying out analyses of multiple batches, the time required for transportation of the sample to an accredited laboratory, the carrying out of the actual analysis and the interpretation of the results, as the batch cannot be accepted before completion of all stages of the analysis.

These shortcomings, combined with the heterogeneity of the samples tested and the need for reliable methods for real-time detection of mycotoxins,

lead to challenges for applying conventional and established methods of analysis and the implementation of ELISA-based methods of incoming inspection. Experience shows that the most common qualitative methods of incoming inspection are immunochromatographic rapid tests for mycotoxin analysis.

For this study, two types of analysis were carried out on the same batch of peanuts, C 23/0817, subjected to an incoming inspection. The results are shown in Table 2.

Table 2: Results of the test for presence of aflatoxin in peanuts batch C 23/0817

Sample No.	Mycotoxins	HPLC	Immunochromatographic rapid tests
		Test results (µg/kg) (value and uncertainty)	Test results Qualitative analysis
Sample 1	Aflatoxin B1	0.25 ± 20 ref %	Negative result
	Total aflatoxins B1, B2, G1 and G2	<1.0	-
Sample 2	Aflatoxin B1	0.25 ± 20 ref %	Negative result
	Total aflatoxins B1, B2, G1 and G2	<1.0	
Sample 3	Aflatoxin B1	0.30 ± 20 ref %	Negative result
	Total aflatoxins B1, B2, G1 and G2,	<1.0	
Sample 4	Total aflatoxins B1, B2, G1 and G2	not tested	Negative result
Sample 5	Total aflatoxins B1, B2, G1 and G2	not tested	Negative result
Sample 6	Total aflatoxins B1, B2, G1 and G2	not tested	Negative result

The analyses carried out by both methods did not reveal the presence of mycotoxins in the tested sample from peanuts batch C 23/0817. This incoming inspection allows the batch to be accepted. The time spent for analysis by the method of HPLC was 48 hours, and that for analysis through immunochromatographic rapid tests was 30 minutes (including the time for preparation of the sample for analysis). From an economic perspective, the traditional analysis method required several times higher costs than the rapid tests for analysis.

In case of positive results in the incoming inspection and deviation from the specification, the controller of the batch must dispatch the peanuts or peanut products for storage. This would require that the batch be isolated from the usable raw materials and stored separately until a decision is taken to submit a claim to the supplier.

IV. Conclusions

Mycotoxins, and in particular aflatoxins, have been proven to be toxic and carcinogenic even at very low concentrations, which requires sensitive and reliable methods of detection. The carrying out of analyses upon the incoming inspection of peanuts and peanut products is critical to verify their compliance with the safety requirements. The general analysis of mycotoxins by the HPLC method, performed in an accredited laboratory, provides reliable and accurate results, but are expensive and takes too much time to complete. This requires the introduction of rapid qualitative analysis tests that do not enable quantification of the test indicator but allow for real-time results of the analysis and a timely disposition of raw materials which do not meet the regulatory requirements for the presence of mycotoxins. We have concluded that producers who use peanuts as an ingredient in ready-to-eat foodstuffs should implement rapid tests for the analysis of mycotoxins to increase efficiency and prevent cross-contamination. In addition, it is necessary to pay due attention to the creation of appropriate conditions for the processing and storage of peanut-based finished and semi-finished products to prevent the development of mycotoxins in these materials.

References Références Referencias

1. Bata, A. & Lásztity, R., 1999. Detoxification of mycotoxin-contaminated food and feed by microorganisms. Trends in Food Science & Technology, 10(6-7), pp. 223-228.
2. Commission Regulation (EC), 2006. Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuff. Office for Official Publications of the European Communities, OBL 364(5), pp. 5-24.
3. Cotty, P. J. & Jaime-Garcia, R., 2007. Influences of climate on aflatoxin producing fungi and aflatoxin contamination. International journal of food microbiology, 119(1), pp. 109-115.
4. Creppy, E., 2002. Update of survey, regulation and toxic effects of mycotoxins in Europe. Toxicology letters, 127(1), pp. 19-28.

5. De Oliveira, C. A. & Corassin, C. H., 2014. Aflatoxins. 1st ed. London, England: Future Science Ltd.
6. Dorner, J. W., 2008. Management and prevention of mycotoxins in peanuts. Food Additives and Contaminants, 25(2), pp. 203-208.
7. EFSA Panel, 2004. Opinion of the Scientific Panel on contaminants in the food chain [CONTAM] related to Aflatoxin B1 as undesirable substance in animal feed. EFSA Journal of European Food Safety Authority (EFSA), 2(3), pp. 1-36.
8. EFSA Panel, 2013. Aflatoxins (sum of B1, B2, G1, G2) in cereals and cereal-derived food products. Journal of European Food Safety Authority (EFSA), 10(3), pp. 1-25.
9. EFSA Panel, 2018. Effect on public health of a possible increase of the maximum level for 'aflatoxin total' from 4 to 10 μg/kg in peanuts and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs. Journal of European Food Safety Authority (EFSA), 16(2), pp. 1-32.
10. Goldblatt, L., 2012. Aflatoxin: scientific background, control, and implications. 1st ed. London: Elsevier.
11. Gourama, H. & Bullerman, L. B., 1995. Aspergillus flavus and Aspergillus parasiticus: Aflatoxigenic fungi of concern in foods and feeds: A review. Journal of Food protection, 58(12), pp. 1395-1404.
12. King, J. C., Blumberg, J., Ingwersen, L. & Jenab, M., 2008. Tree nuts and peanuts as components of a healthy diet. The Journal of nutrition, 138(9), pp. 1736-1740.
13. Parmar, R. S. et al., 1997. Estimation of aflatoxin contamination in preharvest peanuts using neural networks. Transactions of the ASAE USA, 40(3), pp. 809-813.
14. Singh, B. & Singh, U., 1991. Peanut as a source of protein for human foods. Plant Foods for Human Nutrition, 41(2), pp. 165-177.
15. Torres, A. M., Barros, G. G. & Palacios, S. A., 2014. Review on pre-and post-harvest management of peanuts to minimize aflatoxin contamination. Food Research International, 62(1), pp. 11-19.

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Global Journal of Medical Research: L
Nutrition & Food Science
Volume 21 Issue 1 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

Nutritive and Antinutritive Values of Ready-To-Use Foods based on Local Ingredients for the Recovery of Moderate Acute Malnourished Children in Côte d'Ivoire

By Audrey Herbert Yépié, Ibrahima Cissé, Nina Laurette Ahuéfa, Louise A.Anin Atchibri & Odile S. Aké-Tano
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Abstract- Moderate acute malnutrition is one of the most common nutritional disorders among young children in Côte d'Ivoire. For treating this condition, ready-to-use foods have been found to be the most effective. However, their high cost and the recurrent stock breaks lead to national unavailability whose local production can fill and ensure sustainable care. This study has been set to assess the nutritional and anti-nutrient value of ready-to-use foods formulated with locally available ingredients. For doing this, four formulae meeting the recommended nutritive needs for moderately acutely malnourished children aged 6 to 59 months have been produced using traditional methods and household equipment. The cocoa (LF-1 and LF-3) and cashew (LF-2 and LF-4) formulae contained rice, soy, sugar, oil, and egg. The latter has been added to FL-3 and FL-4. All formulae presented biochemical compositions (proteins, fats, carbohydrates, and energy except fiber and ash) close to *Plumpy'Sup*®.

Keywords: ready-to-use foods, moderate acute malnutrition, children from 6 to 59 months, enriched egg, cocoa, cashew nut, côte d'ivoire.

GJMR-L Classification: NLMC Code: QY 145

Strictly as per the compliance and regulations of:

Nutritive and Antinutritive Values of Ready-To-Use Foods based on Local Ingredients for the Recovery of Moderate Acute Malnourished Children in Côte d'Ivoire

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Abstract- Moderate acute malnutrition is one of the most common nutritional disorders among young children in Côte d'Ivoire. For treating this condition, ready-to-use foods have been found to be the most effective. However, their high cost and the recurrent stock breaks lead to national unavailability whose local production can fill and ensure sustainable care. This study has been set to assess the nutritional and anti-nutrient value of ready-to-use foods formulated with locally available ingredients. For doing this, four formulae meeting the recommended nutritive needs for moderately acutely malnourished children aged 6 to 59 months have been produced using traditional methods and household equipment. The cocoa (LF-1 and LF-3) and cashew (LF-2 and LF-4) formulae contained rice, soy, sugar, oil, and egg. The latter has been added to FL-3 and FL-4. All formulae presented biochemical compositions (proteins, fats, carbohydrates, and energy except fiber and ash) close to *Plumpy'Sup®*. However, their mineral profile partially covers the recommended needs, which could be corrected by supplementation. On the other phytonutrient composition reveals that they are as rich as *Plumpy'Sup®* in polyphenols and flavonoids but with lower levels of tannins, oxalates and phytates. This latter anti-nutrient would only limit the bioavailability of iron. Ultimately, the consumption of ready-to-use foods made from local ingredients would be an attractive alternative in sustainable management of acute malnutrition in Côte d'Ivoire.

Keywords: ready-to-use foods, moderate acute malnutrition, children from 6 to 59 months, enriched egg, cocoa, cashew nut, côte d'ivoire.

Resumé- La malnutrition aiguë modérée est l'un des troubles nutritionnels le plus rencontré chez les jeunes enfants en Côte d'Ivoire. Pour traiter cette affection, les aliments prêts à l'emploi s'avère être les plus efficaces. Cependant, leur coût élevé et les ruptures de stocks récurrents entrainent une indisponibilité nationale dont la production locale pourra combler et assurer une prise en charge durable. L'objectif de cette étude est d'évaluer la valeur nutritive et antinutritive des aliments prêts à l'emploi formulés à base d'ingrédients localement disponibles. Pour cela, quatre formules répondant aux besoins nutritionnels recommandés chez les enfants malnutris aigus modérés de 6 à 59 mois ont été produites en utilisant des méthodes traditionnelles et équipements domestiques. Les formules à base de cacao (FL-1 et FL-3) et d'anacarde (FL-2 et FL-4) contenaient du riz, soja, sucre, huile et œuf. Ce dernier est uniquement ajouté aux formules FL-3 et FL-4.Les formules locales ont présenté des compositions biochimiques (protéines, lipides, glucides et énergétiques à l'exception des fibres et cendres) proches du *Plumpy'Sup®*. Cependant, leur profil minéral couvre partiellement les besoins recommandés; ce qui pourrait être corrigé par une supplémentation. Par contre, la composition en phytonutriments révèle qu'elles sont aussi riches en polyphénols et flavonoïdes que le *Plumpy'Sup®*mais avec des teneurs plus faibles en tanins, oxalates et phytates. Ce dernier anti-nutriment limiterait uniquement la biodisponibilité du fer. En définitive, la consommation d'aliments prêts à l'emploi élaborés à partir d'ingrédients locaux serait une alternative intéressante dans la prise en charge durable de la malnutrition aiguë en Côte d'Ivoire.

Mots clés: aliment prêt à l'emploi, malnutrition aiguë modérée, enfants de 6 à 59 mois, œuf enrichi, cacao, anacarde, côte d'ivoire.

I. Introduction

Undernutrition is the most frequent nutritional disorder in developing countries. It remains one of the most common causes of morbidity and mortality in children under five worldwide [1].

Acute malnutrition remains one of the three forms of undernutrition that most degrades the lives of poor communities in low- and middle-income countries [2]. Globally, 52 million children (7.7%) under five that is one in twelve of this age group suffer from acute malnutrition [3, 4], which is associated with 1 to 2 million preventable children deaths every year [5]. Among them, 34 million (or 14 million in Africa) are affected by moderate acute malnutrition (MAM), while 17 million suffer from severe acute malnutrition (SAM) [3].

In Côte d'Ivoire, the prevalence of acute malnutrition has decreased by 100% over five years

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(from 7% to 6% between 2012 and 2016) [6]. Among the 6%, MAM affects 4.8%, that is 80% of cases, while SAM affects 1.2% (20% of cases). In addition, the prevalence of acute malnutrition from the 6 to 24 month age group is around 10% (9.77%) [6] which is considered by WHO to be a solemn threshold that requires emergency intervention [7]. Now, this age group included in the first 1000 days of life is considered to be the most decisive period for influencing long-term nutrition and health outcomes [5]. Also, to prevent a worsening of their nutritional state and their progression to the severe form, the management of MAM in Côte d'Ivoire should be considered a public health priority.

For combatting this condition, Foods have been designed for Special Medical Purposes. Among them, Ready-to-Use Foods (RUFs) prove to be the most effective in managing acute malnutrition [8]. They improve the recovery rate of acutely malnourished children in sub-Saharan Africa [9]. However, shipping costs, delays, priority, as well as donor fatigue, lead to periodic unavailability of RUFs in Côte d'Ivoire, which compromises its effectiveness in fighting against malnutrition.

In addition, the milk- and peanut-based RUFs commonly known as *Plumpy'Nut®* and *Plumpy'Sup®*, respectively used in the treatment of SAM and MAM, are expensive [10, 11]. As a result, sustainable treatment with these RUFs can be hard in the absence of local production [12]. For this production, replacing the milk in RUFs with soybeans could reduce its cost and and/or increase its availability.

For an ingredient to be described as local, a country must have 500 metric tons or more of a given available, whether nationally produced or imported, in the locale of RUTF production [14] with a regular supply. Thus, Côte d'Ivoire is the first producer of cocoa and cashew nuts in the world with respective productions of 2.2 million tons (Mt) for the 2018/2019 campaign [15] and 761,000 tons in 2018 [16]. According to the United States Department of Agriculture (USDA), Ivorian production of unhulled rice is around 2.231 Mt for the 2018/2019 season compared to 1.45 Mt of milled rice [17]. Côte d'Ivoire is also the second African producer of crude palm oil with 500,000 tons per year [18]. Soybean production data is not updated. However, the Office of Aid for the Marketing of Food Products (OCPV) reports a regular supply on local markets (Abidjan, Bouaké, Yamoussoukro, Man).

It is in this context that low-cost ready-to-use foods (RUFs) were developed using local ingredients. The objective of the present study is, therefore to assess nutritional and antinutritive quality of these RUFs in comparison with *Plumpy'Sup®* to meet the nutrients recommended by the WFP for the management of moderate acute malnutrition in children aged six at 59 months.

II. Materials and Methods

a) Materials

The raw materials used for the production of RUF in the form of spreads are cocoa pods (*Theobroma cacao*, var. Forastero), cashew paste (*Anacardium occidental* L.), milled rice (*Oryza indica*, var. Bouake), soya beans (*Glycine sp*), chicken eggs (*ISA waren*), sugar and refined palm oil.

The cocoa comes from the plantations of the Research and Experimentation Station of the National Agronomic Research Center (CNRA) in Divo. Cashew paste and white milled rice were purchased from the companies SARAYA in Bouaké and CODERIZ in Adzopé. Eggs enriched in omega three by the seeds of Euphorbia (*Euphorbia heterophylla* L.) were produced on the farm of the breeding center of the National Institute for Agricultural Vocational Training (INFPA) in Bingerville. Soybeans, sugar, and oil were bought from the local market. Finally, the *Plumpy'Sup®* given by Nutriset® was used as a reference.

b) Methods

i. Formulation of RUFs

Theoretical formulation of RUFs was carried out using linear programming [19] to identify combinations of ingredients that meet the nutritional needs of children under five years suffering from acute malnutrition [20]. Thus, four (4) RUFs were formulated and noted local formulae 1, 2, 3, and 4 (LF-1, LF-2, LF-3, and LF-4). Except added egg in LF-3 and LF-4, all local cocoa formulae LF-1 and LF-3 and those containing cashew nuts LF-2 and LF-4 have used the following ingredients: soy, rice, oil, and sugar *(Table I).*

Table I: RUF formulations

Ingredients (%)	LF-1	LF-2	LF-3	LF-4
Rice flour	24	22	23	23
Soya flour	29	30	28	26
Cocoa paste	17		17	
Cashew paste		17		17
Egg powder			03	03
Refined palm oil	20	21	19	21
Ice sugar	10	10	10	10
Total	**100**	**100**	**100**	**100**

ii. *Ingredient treatments*

Rice flour has been obtained from the white milled rice. The latter, after having been cleaned (sorting, winnowing, and washing with water three times), was precooked in a microwave oven for 3 min. The precooked rice was then roasted in a frying pan at 120-130 ° C for 30 to 40 min [21], pulverized in a mill (PHILIPS®, HR2056), and sieved using a 150 μm mesh sieve.

Soybean meal has been obtained from soybeans that were cleaned and then soaked in water containing 1% sodium bicarbonate [22]. The soaking has been carried out in a seed/water ratio of 3:10 (w/v) for eighth [23]. The soaked seeds were then drained, skinned, and then precooked in a microwave oven for 3 to 5 min. The precooked seeds were finally roasted in a pan at 120-130 ° C for 50-70 min, respectively, cooling, grinding using a mill, and sieving at 300 μm.

The cocoa mass has been obtained from the cocoa pods. These are first podded to extract the beans, which will then be fermented under banana leaves for six days [24]. The fermented beans were oven-dried for 1 to 3 days, then roasted at 130 ° C for 30 to 40 min. The roasted beans were finally shelled by hand, winnowed with a hairdryer, crushed, and then ground in a mortar to obtain a paste.

Icing sugar has been obtained from powdered white sugar (≈ 1000 μm). The latter was crushed using a mill and then sieved to get a powder (150 μm).

Egg powder has been obtained from chicken eggs. These have first been broken to remove the shells. The liquid obtained was homogenized in a multifunction mixer. It was immediately oven-dried at 45° C for 24 to 48 hours and spreading it on aluminum trays. The dried eggs were ground using a mill and then sieved with a 300 μm diameter sieve.

Cashew nut paste and refined palm oil have been used as such without any treatment or processing.

iii. *Preparation of RUFs*

The preparation of RUFs has been inspired by the methods described by [21] and [25]. RUF's formulae have been prepared by combining the ingredients according to [26].

iv. *Determination of the nutritional and anti-nutritional value of formulae produced*

Water activity and pH were measured using a moisture meter (Moisture Balance, BM-50-1) and a pH meter (Benchtop / mV meter, 210), respectively. The dry matter, lipid, protein, ash, and dietary fiber contents have been determined according to [27] method in triplicate. The carbohydrate content was estimated by differential calculation [28]. The ash obtained was used to determine the mineral profile using the Scanning Electron Microscope, equipped with an X-ray detector (OXFORD Instruments). The calculation of the energy value has been carried out according to the relation given by the conversion coefficient of metabolized energy called general Atwater factors [29].

The phenolic compounds have been extracted with methanol according to the [30] method. These extracts have been used to determine the contents of polyphenols, flavonoids, and tannins according to the respective methods described by [30], [31], and [32]. On the other hand, the oxalate and phytate contents have been determined on the samples according to the methods described by [33] and [34]. The bioavailability of the minerals was determined by [35] and [36] by measuring the molar ratios Phytate/Iron, Phytate/Zinc, Phytate/Calcium, Phytate×Calcium/Zinc, and Oxalate/Calcium.

v. *Statistical analyzes*

The data collected was first entered in the Excel spreadsheet. Then, their statistical processing has been carried out using R software version 3.5.2. The results have been expressed as the mean ± standard error. After a one-way analysis of variance (ANOVA), the comparison of the means has been carried out by the Newman-Keuls test (at the 5% level)

III. Results

Table II shows the physicochemical composition of the local (LF-1, LF-2, LF-3, and LF-4) and reference (*Plumpy'Sup*® (PS)) formulae. Local formulae had lower pH (5.70 to 6.19), ash (1.80 to 1.87), and available carbohydrate (GD) (35.06 to 41.19%) values than those of PS (6.25; 4.70 g/100g and 42.24%). LF-4and LF-1recorded the highest values of water activity (Aw) (0.49) and dietary fiber (8.49 g/100g), respectively. LF-2, LF-3, and LF-4 had the highest moisture contents, respectively, 2.40, 2.23, and 2.42%, whileLF-3, LF-1and PS recorded the highest dry matter (DM) with respective rates of 97.77, 97.80, and 97.95%. Formulae, including egg powder (LF-3 and LF-4), had the highest protein content (15.42 and 15.34 g/100g), followed by LF-1, LF-2and that of PS, which had the lowest protein content (13.86 g/100g). Lipid contents were highest in cocoa-based formulaeLF-1(37.28 g/100g) and LF-3 (37.14 g/100 g). Energy value of cocoa-based formulae LF-1(536.15 kcal/100g) and LF-3 (536.19 kcal/100 g) was significantly ($p < 0.05$) lower than that of cashew-based formulae LF-2 (539.34 kcal/100g), LF-4 (538.06 kcal/100g) and PS (539.11 kcal/100g).

Table II: Physicochemical compositions of reference and local formulae

Parameters	PAM recommendations		*Plumpy'Sup®*	LF-1	LF-2	LF-3	LF-4
	Min	Max					
pH	_	_	6.25 ± 0.01 [a]	5.70 ± 0.02 [c]	6.17 ± 0.02 [b]	5.73 ± 0.02 [c]	6.19 ± 0.01 [b]
A_w	_	0.6	0.26 ± 0.02 [d]	0.30 ± 0.02 [c]	0.41 ± 0.01 [b]	0.29 ± 0.02 [c]	0.49 ± 0.03 [a]
Humidity (%)	2.5 *	5 *	2.05 ± 0.07 [b]	2.20 ± 0.02 [b]	2.40 ± 0.18 [a]	2.23 ± 0.03 [ab]	2.42 ± 0.04 [a]
DM (%)	_	_	97.95 ± 0.07 [a]	97.80 ± 0.02 [a]	97.60 ± 0.18 [b]	97.77 ± 0.03 [a]	97.58 ± 0.04 [b]
Protein (g/100g)	11	16	13.86 ± 0.07 [d]	14.39 ± 0.02 [c]	15.22 ± 0.07 [b]	15.42 ± 0.03 [a]	15.34 ± 0.02 [a]
AC (%)	_	_	42.24 ± 0.28 [a]	35.76 ± 0.08 [d]	39.87 ± 0.19 [c]	35.06 ± 0.11 [e]	41.19 ± 0.06 [b]
Lipid (g/100g)	26	36	34.97 ± 0.25 [c]	37.28 ± 0.05 [a]	35.44 ± 0.02 [b]	37.14 ± 0.16 [a]	34.66 ± 0.01 [d]
Ash (g/100g)	_	_	4.70 ± 0.01 [a]	1.87 ± 0.01 [b]	1.81 ± 0.05 [b]	1.85 ± 0.06 [b]	1.80 ± 0.03 [b]
Fiber (g/100g)	_	_	2.18 ± 0.04 [e]	8.49 ± 0.02 [a]	5.25 ± 0.05 [c]	8.3 ± 0.02 [b]	4.59 ± 0.03 [d]
EV (kcal/100g)	510	560	539.11 ± 1.11[a]	536.15 ± 0.18[b]	539.34 ± 0.98 [a]	536.19 ± 1.11[b]	538.06 ± 0.12 [a]

*Source: * [37]; Aw: Water activity; DM: Dry matter; AC: Available Carbohydrates; EV: Energy Value; LF-1: Local formula based on cocoa / rice / soybeans; LF-2: Local formula based on cashew / rice / soybeans; LF-3: Local formula based on cocoa / rice / soya / egg; LF-4: Local formula based on cashew / rice / soy / egg. The digits in the background represent the highest value (s) for each parameter.*

Mineral profile of reference and local formulae has been presented in *Table III*. Except sodium, and manganese contents, all local recorded significantly lower mineral values ($p < 0.05$) than those of PS. Analysis of macroelements, trace elements and then Ca/P and Zn/Cu ratios showed that all local formulae do not meet the limits of the recommendations. Likewise, these limits are not respected in the PS for the contents of K, Ca, P, and the Zn/Cu ratio.

Table III: Mineral profile of reference and local formulae

Minerals (mg/100g)		PAM recommendations		*Plumpy'Sup®*	LF-1	LF-2	LF-3	LF-4
		Min	Max					
Macro-elements	Na	_	270	48.74 ± 4.11 [bc]	45.68 ± 2.62[c]	65.94 ± 2.65 [a]	53.98 ± 1.39 [b]	66.36 ± 3.84 [a]
	K	900	1400	841.75 ± 8.41 [a]	437.54 ± 2.59 [b]	381.84 ± 6.28 [c]	387.92 ± 0.32 [c]	354.38 ± 1.16[d]
	Ca	535	750	335.54 ± 7.87 [a]	59.72 ± 0.68 [b]	47.68 ± 1.48 [c]	62.74 ± 1.03 [b]	60.07 ± 2.07 [b]
	P	450	750	382.56 ± 5.43 [a]	192.84 ± 1.23 [d]	201.74 ± 0.52 [c]	199.20 ± 1.57 [cd]	223.34 ± 5.29 [b]
	Mg	150	225	167.07 ± 5.41 [a]	90.24 ± 0.97 [b]	71.44 ± 1.92 [d]	79.46 ± 1.26 [c]	76.12 ± 3.80 [cd]
Oligo-elements	Zn	11	14	10.50 ± 0.27 [a]	3.12 ± 1.51 [bc]	2.42 ± 0.10 [c]	4.44 ± 0.32 [b]	2.22 ± 0.41 [c]
	Fe	10	14	11.44 ± 0.98 [a]	2.37 ± 0.39 [b]	2.05 ± 0.21 [b]	2.16 ± 0.21 [b]	1.98 ± 0.00 [b]
	Cu	1,4	1,9	3.13 ± 0.72 [a]	2.43 ± 0.32 [abc]	1.63 ± 0.31 [bc]	1.30 ± 0.64 [c]	2.58 ± 0.41 [ab]
RatioNa/K*			1	0.05	0.10	0.17	0.14	0.19
Ca/P**		0.7	1.3	0.88	0.31	0.24	0.31	0.27
Zn/Fe***		0.8	3.5	0.91	1.32	1.18	2.06	1.12
Zn/Cu***		5	20	3.35	1.28	1.48	3.43	0.86

*Source: * [38] ; ** [39] ; *** [40]*

Phytochemicals contents of all formulae have been presented in *Table IV*. Cocoa-based formulae (LF-1 and LF-3) had higher levels of polyphenols and flavonoids than those of PS and cashew-based formulae (LF-2 and LF-4). Local recorded lower levels of tannins, oxalates, and phytates than those of PS.

Table IV: Phytochemical compositions of reference and local formulae

Formulae	Compounds (mg/100g)				
	Polyphenols	Flavonoids	Tannins	Oxalates	Phytates
Plumpy'Sup®	483.38 ± 8.63 [b]	164.64 ± 2.08[bc]	154.40 ± 10.36 [a]	82.00 ± 4,00 [a]	239.23 ± 14.85 [a]
LF-1	581.28 ± 13.81 [a]	186.58 ± 1.10[a]	73.50 ± 1.76 [b]	44.00 ± 0.00 [d]	36.48 ± 0.64 [b]
LF-2	305.33 ± 3.47 [c]	166.71 ± 12.14[bc]	59.08 ± 1.43 [c]	66.73 ± 1.27 [b]	38.59 ± 2.52 [b]
LF-3	554.92 ± 30.36 [a]	175.54 ±1.10[ab]	64.53 ± 1.31 [c]	34.10 ±1.10 [e]	33.05 ± 0.83 [b]
LF-4	284.45 ± 3.81 [c]	151.25 ± 9.94[c]	55.23 ± 1.73 [c]	55.00 ± 0.00 [c]	35.47 ± 0.83 [b]

The Phy/Fe, Phy/Zn, Phy/Ca, Phy×Ca/Zn, and Oxa/Ca molar ratios, indicative of the bioavailability of Fe, Zn, and Ca are given in *Table V*. The results indicate that only the Phy/Fe molar ratio of all the formulae is not respected. Likewise, the Phy×Ca/Zn ratio has been not respected in PS (*Plumpy'Sup®*).

Table V: Molar ratios between anti-nutritional compounds and minerals in reference and local formulae

Formulae	Molar Ratios				
	Phy/Fe	Phy/Zn	Phy/Ca	Phy×Ca/Zn	Oxa/Ca
Plumpy'Sup®	1.77	2.26	0.04	18.89	0.11
LF-1	1.30	1.16	0.04	1.73	0.33
LF-2	1.59	1.58	0.05	1.88	0.62
LF-3	1.29	0.74	0.03	1.15	0.24
LF-4	1.52	1.58	0.04	2.37	0.41
Normes	< 0.5 ou 1 [a]	< 15 [b]	< 0.17 [c]	< 3.5 [d]	< 2 [e]

Source: [a][41] ou [42] ; [b][43] ; [c][44] ; [d][45] ; [e][46]

IV. Discussion

Results of the physicochemical composition *(Table II)* show overall that all formula met WFP recommendations [20] for ready-to-use foods intended for malnourished children. They have been characterized by low water activity (<0.6), and low humidity (<5 g/100g) which are comparable to those found by [37], [47] and [48]. These low recorded rates could have been explained by the drying, roasting and grinding processes used in the production. These rates would therefore be beneficial for better and long shelf life. In addition, cocoa-based formulae (LF-1 and LF-3) recorded the lowest pH values, which could have been explained by fermented ingredients in the production process.

Protein contents of local formulae (14.39 to 15.42 g/100g) were higher than PS (13.86 g/100g). These values are lower than those determined by [49] (17.06 g/100g) and [48] (17.60 g/100g) respectively in RUFs based on soy and whey protein but fall within the range of 11.42 to 15.6 g/100g described by [47], [49] and [50] for RUFs based on whey protein.

However, our formulae had higher levels than those reported by [37] (13.4 to 14.1 g/100g) for sesame-based RUFs. In addition, the incorporation of egg powders in LF-3 and LF-4 formulae had higher protein contents than those made only from ingredients of plant origin (LF-1 and LF-2).

For lipid contents, cocoa-based formulae (LF-1 and LF-3) were higher than PAM recommendation (26 to 36 g/100 g). These high values compared to those formulae (PS, LF-2, and LF-4) would be due to the incorporation of the cocoa mass. Malnourished children have a high energy requirement [50]. They, therefore, need a diet rich in fat. These lipids are also necessary for the absorption of vitamins A and E [52], which are vital for rapid recovery and reducing the incidence associated with malnutrition.

Ash contents of all local formulae are much lower than that of PS because the latter has been supplemented with minerals and vitamins [53]. In addition, the high fiber contents of the cocoa-based formulae are close to those found by [51] (7.85 g/100 g) in Uganda in a therapeutic food based on sorghum and peanut for the treatment of MAM. Fiber plays an essential biochemical and physiological role indigesting foods. Unfortunately, due to the clear limitations of the evidence on the subject caused by insoluble or soluble fiber in these moderately malnourished children, no limits have been set [51]. However, extensive preclinical studies should have been carried out to establish a standard in this matter.

The carbohydrate content and energy density of all formulae are adequate to provide enough energy for a child to recover from moderate malnutrition. Finally, the physicochemical composition reveals except of the fiber and ash contents, that the protein, fat, carbohydrate, and energy values are generally comparable to those of *Plumpy'Sup®*.

The results of the mineral profile *(Table III)* revealed a significant difference between local formulae and PS. This result is mainly due to the addition of mineral and vitamin supplements in PS. Thus, the mineral profile of our formulae does not meet the majority of recommendations for the care of children suffering from MAM. In practice, no food can provide the minerals necessary to correct such deficiencies and ensure de novo tissue synthesis. These results agree with the findings of [52], who reported that formulations using local foods do not achieve these recommendations except through supplementation. Thus, to cover all the target's needs and ensure rapid and efficient recovery, it would be essential to supplement our local formulae with minerals.

Some minerals can also compete, which could cause losses. Thus, ratios have been established to ensure adequate absorption and proper functioning of the body. The first ratio is that of Na/K. This is of great interest in preventing high blood pressure (HBP). Na/K ratio of less than one has been recommended [54]. Na/K ratios of all local formulae are less than 1, which suggests that they have a good capacity to prevent HBP and would therefore be beneficial for the health of children and particularly for the undernourished ones.

Second ratio is of Ca/P. Foods rich in protein and P may promote the loss of Ca in the urine [55]. [39] suggests that this ratio would be between 0.7 and 1.3 in

children over six months for high quality absorption, while it would be between 0.5 and 1 [38]. However, the results showed a low Ca/P ratio, which could lead to a loss of Ca in the urine more than usual, hence the need to supplement local formulae. The third one is Zn/Fe ratio. A ratio of 0.8 to 3.5 has been established to ensure adequate absorption [40]. Thus, all formulae respected this standard. The last ratio is that of Zn/Cu. Reference and local formulae exhibited ratios varying from 0.86 to 3.43, which indicates that they should have been supplemented with Zn rather than Cu to meet the standard [40].

The results of phytochemical values *(Table IV)* indicated a high content of total polyphenols of local formulae, which would be beneficial for malnourished children who have a slowed metabolism and a weakened immune system. Indeed, polyphenols play several biological roles, notably in anti-inflammatory activity [56] and the prevention of cardiovascular diseases [57].

Regarding the flavonoid contents of formulae studied, they are higher than those reported by [58] and [59] respectively in infant formulae based yam/soy (3.35 to 76.58 mg / 100 g DM) and on corn/sesame/moringa (0.88 to 85.85 mg / 100 g DM). As for oxalate contents, they are much lower than those of [60] obtained in formulae based on cereals enriched with soya, egg yolks, and crayfish (780 mg / 100 g) and below the lethal dose (4000 at 5,000 mg/day) [61].

The low tannin contents recorded in local formulae could result from soybean soaking conditions carried out during production. Indeed, during steeping, the tannin contents are markedly lower than those of polyphenols, definitely because of their cooler solubility [62]. In addition, the use of bicarbonate in the soybean steeping solution must have increased its alkaline properties allowing greater solubilization of tannins. Indeed, [63] observed a reduction in tannins in sorghum grains after soaking in an alkaline solution before their malting. In addition, tannin contents of local formulae are lower than those of [64] obtained during the preparation of local formula based on sorghum, peanuts, whey, and honey (943 mg/100g).

The reduction in phytate content of all local formulae could be attributed to the phytase activity contained in soybean during their soaking. These results agree with the work of [65] and [66], who respectively reported that soaking reduced phytate content by 28% in pigeon peas and by 25-30% in mung beans. Although we did not determine this particular amount in our study, some information inthe literature [67] suggests that this may indeed be the case.

However, the exact effect of anti-nutritional compounds on mineral absorption depends on their relative concentration in formulae. Thus, a theory has been advanced, supported by several animal experiments [61, 68], that the phytate/iron, zinc, or calcium (Phy/Fe, Phy/Zn, or Phy/Ca) molar ratios of food can serve as an index of respective assimilability of iron, zinc, and calcium. The results of *Table V* indicated that Zn and Ca have been easily assimilated in all formulae. On the other hand, Phy/Fe ratios of local ones (1.29 to 1.59) and PS (1.77) are higher than the standard [41, 40], which could lead to a marginal iron deficiency resulting from its poor assimilation.

This finding was also reported by [69] for the reference formula (*Plumpy'Nut®*) used in severely acutely malnourished children. However, [70] and [71] suggest that the bioavailable iron content of food has been expressed by taking into account compounds that can positively influence iron absorption. These are vitamin C, citric acid, animal proteins, and sugars (lactose and maltodextrins).

Thus, the absorption of iron in subjects consuming meals containing corn, wheat, and rice, is approximately doubled by the addition of 25 mg of vitamin C and can be multiplied by 3 to 6 times when 50 mg are added [72]. This favorable effect of vitamin C, due to the preferential affinity of iron for this compound over chelating compounds, is most evident when foods are rich in phytates or phenolic compounds [73, 74]. These conclusions agree with the results of studies carried out in severely acutely malnourished children comparing the effectiveness of a local formulation based on corn/sorghum/soya and *Plumpy'Nut®*. Their vitamin C contents were respectively 329 and 53 mg/100g, those of phytates were 420 and 255 mg/100g while those of iron were 43.8 and 12 mg/100g [69]. Therefore, the amount of vitamin C contained in PS (60 mg/100 g) [53] may promote iron absorption despite their high phytate content (239.23 mg/100 g).

In addition, the work of [75] has shown that the inhibitory role of phytate in the absorption of zinc has been accentuated by the calcium content in food. [45] suggested that the assimilability of zinc in food could be estimated more satisfactorily by calculating the Phy*Ca/Zn ratio. Analysis of the results indicates that this ratio is less than 3.5 in all local formulae. Thus, the phytate contents of these formulae could not interfere with the absorption of zinc. Regarding the Oxa/Ca molar ratio, it appears that this ratio should be of the order of 2 for oxalic acid to significantly interfere with calcium absorption [46]. The results of all formulae indicate that these ratios oscillate between 0.11 (PS) and 0.62 (LF-2), which would show that the oxalate contents of these formulae could not interfere with the bioavailability of calcium.

V. Conclusion

Local production of RUFs is crucial for the sustainable management of malnutrition. This study demonstrated that it is possible to produce RUF from locally available ingredients while using traditional

methods and domestic equipment. For doing this, four local formulae have been produced, two of which are based on cocoa (LF-1 and LF-3) and two others are based on cashew nuts (LF-2 and LF-4). Analysis of the physicochemical composition of these formulae revealed that except fiber and ash contents, protein, lipid, carbohydrate, and energy values are closed to those of *Plumpy'Sup*® while respecting WFP standards for the preparation of supplementary ready-to-use foods (RUSF). However, a mineral profile of local formulae indicates that they only partially cover the mineral needs recommended by WFP. These formulae could have been corrected by supplementation to ensure rapid and effective recovery.

The study of phytonutrient composition shows that local formulae are an excellent source of polyphenols and flavonoids with values sometimes higher than those of *Plumpy'Sup*®. In addition, tannin, oxalate, and phytate contents of local formulae are lower than those of *Plumpy'Sup*®. Apparent bioavailability assessment indicates that except the Phy/Fe ratio, all local formulae have a good absorption capacity of zinc and calcium.

Ultimately, consumption of RUFs made from local ingredients would be an attractive alternative in the sustainable management of acute malnutrition. However, it would be necessary to continue this study by seeking to supplement these RUFs in vitamins/minerals and evaluate their shelf life and microbiological quality. Sensory analyzes should also have been carried out.

Thanks

We would like to thank the management of *Nutriset*® and more particularly M. Julien PLANCHON and Ms. Yamina MANCEL for providing us with *Plumpy'Sup*® (reference feed). Our thanks also go to the entire technical team of the Nutrition and Food Security laboratory at Nangui Abrogoua University.

Conflict of Interest

Authors declare that they have no conflict of interest.

Bibliographical References

1. T. H. Musa, H. H. Musa, E. A. Ali, and N. E. Musa, "Prevalence of malnutrition among children under five years old in Khartoum State, Sudan", *Polish Annals of Medicine,* vol. 21, pp.1-7, 2014.
2. Génération Nutrition (GN), "Malnutrition aiguë: une urgence quotidienne. 10 mesures pour lutter contre la malnutrition aiguë chez les moins de cinq ans", *Rapport de campagne*, 2014. [Online] Available: www.generation-nutrition.org/fr
3. High level Panel of Experts (HLPE), Nutrition et systèmes alimentaires. Rapport du Groupe d'experts de haut niveau sur la sécurité alimentaire et la nutrition du Comité de la sécurité alimentaire mondiale (12ième rapport), Rome, 2018.
4. M. E. Sosanya, G. O. Nweke, L. C. Ifitezue, "Formulation and Evaluation of Ready-To-Use Therapeutic Foods Using Locally Available Ingredients in Bauchi, Nigeria", *European Journal of Nutrition and Food Safety*, vol. 8, no. 1, pp. 1-10, 2018.
5. R. E. Black, C. G. Victora, S. P. Walker, "Maternal and child under-nutrition and overweight in low-income and middle income countries", *Lancet*, vol. 382, no. 9890, pp. 427–451, 2013.
6. Institut National de la Statistique (INS), "Enquête par grappes à indicateurs multiples (MICS), 2016, Rapport des Résultats clés", Abidjan, Côte d'Ivoire, 442 p., 2017.
7. World and Health Organization (WHO), "Physical Status: The Use and Interpretation of Anthropometry", *WHO Technical Report Series*, vol. 854, Geneva, 1995.
8. M. Lazzerini, L. Rubert, P. Pani, "Specially formulated foods for treating children with moderate acute malnutrition in low- and middle-income countries (Review)", *Cochrane Database Systematic Revue*, vol. 6, 2013.DOI: 10.1002/14651858.CD009584.pub2.
9. UNICEF, "Technical requirements of ready-to-use therapeutic foods, request for proposal, RFP-DAN-2013-501715. New York: UNICEF, 2013".
10. V. O. Owino, A. H. Irena, F. Dibari, S. Collins, "Development and acceptability of a novel milk-free soybean-maize-sorghum ready to-use therapeutic food (SMS-RUTF) based on industrial extrusion cooking process", *Maternal and Child Nutrition*, vol. 10, no. 1, pp. 126-134, 2014.
11. Nutriset, "Buy Plumpy'Sup / The Level Market", 2019. https://www.thelevelmarket.com/plumpysup
12. V. Gatchell, V. Forsythe, P.R. Thomas, "The sustainability of community-based therapeutic care (CTC) in nonemergency contexts", *Food and Nutrition Bulletin*, vol. 27, no. 3, pp. S90-98, 2006.
13. M. Manary, "Alternative RUTF Formulas. UNICEF Supply Division", 2015. https://www.unicef.org/supply/files/9_Mark_Manary_Alternative_RUTF_Formulas.pdf
14. Baudelaire, Mieu, Côte d'Ivoire: enfin une augmentation du prix du cacao ?,2018. [Online] Available: www.jeuneafrique.com (September 27, 2018)
15. Agence de Presse Africaine (APA), La campagne cajou officiellement lancée en Côte d'Ivoire avec 800 000 tonnes visées en 2019, 2019. [Online] Available: www.apanews.net (February 20, 2019)
16. COMMODAFRICA, Hausse de 12% des rendements du riz en Côte d'Ivoire, 2018. [Online] Available: www.commodafrica.com (September 10, 2018)
17. Financial Afrik, Côte d'Ivoire: forte baisse du prix d'achat du palmier à huile, 2019. [Online] Available: www.financialafrik.com (May29, 2019)

18. A. H. Yepié, N'G. D. V. Kouakou, I. Bamba, B. Aka, O. S. Aké-Tano, A. L. Anin Atchibri, "Optimization of a local ingredient-based ready to use food using linear programming for the treatment of moderate acute malnutrition in Côte d'Ivoire", *International Journal of Applied Research*, vol. 5, pp. 93-100, 2019.
19. World Food Program (WFP), "Technical Specifications for-Ready-to-Use Supplementary Food-RUSF. WFP, Specification reference: MIXRSF000", 2016.
20. T. Ahmed, N. Choudhury, M. I. Hossain, N. Tangsuphoom, M. M. Islam, S. de Pee, … P. Christian, "Development and acceptability testing of ready-to-use supplementary food made from locally available food ingredients in Bangladesh", *BMC Pediatrics*, vol. 14, no. 164, pp. 1-8, 2014.
21. P. Niraula, "Preparation of ready to use supplementary food (RUSF) for treating moderately acute malnutrition in children aged 6-24 months", Department of Nutrition & Dietetics, Central Campus of Technology Institute of Science and Technology Tribhuvan University, Nepal, 78 p., 2017.
22. T. A. El-Adawy, E. H. Rahma, A. A. El-Bedawy, T. Y. Sobihah, "Effect of soaking process on nutritional quality and protein solubility of legume seeds", *Journal of Food Sciences*, vol. 44, no. 5, pp. 339-343, 2000.
23. L. Ban Koffi, G. H. Ouattara, T. G. Karou, T. S. Guehi, J. G. Nemlin, J. K. Diopoh, "Impacts de la fermentation du cacao sur la croissance de la Flore microbienne et la qualité des fèves marchandes", *Agronomie Africaine*, vol. 25, no. 2, pp. 159-170, 2013.
24. M. I. Ordiz, K. N. Ryan, E. D. Cimo, M. E. Stoner, M. E. Loehnig, M. J. Manary, "Effect of emulsifier and viscosity on oil separation in ready-to-use therapeutic food", *International Journal of Food Sciences and Nutrition*, Early Online, pp. 1-7, 2015. DOI: 10.3109/09637486.2015.1077784.
25. Audrey Herbert Yepié, Ibrahima Cissé, Alassane Meité, Nina Laurette Ahuéfa, Odile S. Aké-Tano & Anin L. Anin-Atchibri. Adding Enriched Eggs in Ready-to-use foods Improve Recovery Rate in Malnourished Rats. *Journal of Food Research*, Vol. 10, No. 1, pp. 1-13, 2021.
26. AOAC, "Official Methods of Analysis of Association of Official Analytical Chemists", 17thed. Gaithersburg, Maryland, USA. Methods 925.10, 65.17, 974.24, 992.16., 2000.
27. FAO/INFOODS, "Directives FAO/INFOODS relatives à la conversion d'unités, de dénominateurs et d'expressions", version 1.0. FAO, Rome, 2015a.
28. FAO/INFOODS, "Directives FAO/INFOODS relatives à la vérification des données sur la composition des aliments avant la publication d'une table/base de données utilisateur", version 1.0. FAO, Rome, 2015b.
29. V. L. Singleton, R. Orthofer, R. M. Lamuela-Raventos, "Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent", *Methods Enzymology*, vol. 299, pp. 152-178, 1999.
30. A. Meda, C. E. Lamien, M. Romito, J. Millogo, O. G. Nacoulma, "Determination of the total phenolic, flavonoid and proline contents in Burkina Fasan honey, as well as their radical scavenging activity", *Journal of Food and Chemitry*, vol. 91, pp. 571-577, 2005.
31. Z. Bainbridge, K. Tomlins, K. Wellings, A. Westby, "Analysis of condensed tannins using acidified vanillin", *Journal of the Sciences of Food and Agriculture*, vol. 29, pp. 77-79,1996.
32. R. A. Day, and A. L. Underwood, "Quantitative analysis", 5th Ed. Prentice Hall pub, 701 p, 1986.
33. M. Latta, and M. Eskin, "A simple and rapid colorimetric method for phytate determination", *Journal of Agriculture and Food Chemistry*, vol. 28, no. 6, pp. 1313-1315, 1980.
34. V. O. Owino, A. H. Irena, F. Dibari, S. Collins, "Development and acceptability of a novel milk-free soybean–maize–sorghum ready-to-use therapeutic food (SMS-RUTF) based on industrial extrusion cooking process", *Maternal and Child Nutrition*, vol. 400, pp. 1-9, 2012.
35. S. Mahfuz, A. Hasan, M. Hassan, S. Saha, M. Islam, M. Billah, S. Islam, "Dietary phytate intake inhibits the bioavailability of iron and calcium in the diets of pregnant women in rural Bangladesh: a cross-sectional study", *BMC Nutrition*, pp. 1-10, 2016.
36. A. Santini, E. Novellino, V. Armini, A. Ritieni, "State of the art of Ready-to-Use Therapeutic Food: A tool for nutraceuticals addition to foodstuff", *Food Chemitry*, vol. 140, pp. 843–849, 2013.
37. S. S. Audu, and M. O. Aremu, "Effect of processing on chemical composition of red kidney bean (*Phaseolus vulgaris* L.) flour", *Pakistan Journal of Nutrition*, vol. 10, no. 11, pp. 1069-1075, 2011.
38. M. H. Golden, "Proposed recommended nutrient densities for moderately malnourished children. *Food and Nutrition Bulletin*, vol. 30, pp. S267–S343, 2009.
39. OMS, "Note technique: Suppléments alimentaires pour la prise en charge de la malnutrition aiguë modérée chez les nourrissons et les enfants âgés de 6 à 59 mois",2012.http://apps.who.int/iris/bitstream/10665/96613/1/9789242504422_fre.pdf
40. A. Lestienne, P. Besancon, B. Caporiccio, V. Lullien-Pellerin, S. Treche, "Iron and zinc in vitro bioavailability in pearl millet flours (Pennisetum glaucum) with varying phytate, tannin, and fiber contents", *Journal of Agriculture and Food Chemitry*, vol. 53, pp. 3240-3247, 2005.

41. R. F. Hurrell, "Phytic acid degradation as a means of improving iron absorption", *International Journal of Vitamins and Nutrition Research*, vol. 74, pp. 445-452, 2004.
42. WHO, 2004. "The treatment of diarrhea: a manual for physicians and other senior health workers", World Health Organization, Geneva, Switzerland.
43. M. Umeta, C. E. West, H. Fufa, "Content of zinc, iron, calcium and their absorption inhibitors in foods commonly consumed in Ethiopia", *Journal of Food Composition and Analysis*, vol. 18, pp. 803–817, 2005.
44. E. N. Mills, J. A. Jenkins, M. J. Alcocer, P. R. Shewry, "Structural, biological, and revolutionary relationships of plant food allergens sensitizing via the gastrointestinal tract", *Critical Reviews in Food Sciences and Nutrition*, vol. 44, pp. 379-407, 2004.
45. C. Tchiégang, and K. Aissatou, "Données ethno-nutritionnelles et les caractéristiques physico-chimiques des légumes feuilles consommés dans la savane de l'Adamaoua (Cameroun)", *Tropicultura*, vol. 22, no. 1, pp. 11-18, 2004.
46. K. N. Ryan, K. P. Adams, S. A. Vosti, M. I. Ordiz, E. D. Cimo, M. J. Manary, "A comprehensive linear programming tool to optimize formulations of ready-to-use therapeutic foods: an application to Ethiopia", *American Journal of Clinical Nutrition*, vol. 100, pp. 1551–1558, 2014.
47. J. M. Weber, K. N. Ryan, R. Tandon, M. Mathur, T. Girma, M. Steiner-Asiedu, … M. J. Manary, "Acceptability of locally produced ready-to-use therapeutic foods in Ethiopia, Ghana, Pakistan and India", *Maternal and Child Nutrition*, pp. 1-9,2016.
48. H. C. Stobaugh, K. N. Ryan, J. A. Kennedy, J. B. Grise, A. H. Crocker, C. Thakwalakwa, … I. Trehan, "Including whey protein and whey permeate in ready-to-use supplementary food improves recovery rates in children with moderate acute malnutrition: a randomized, double-blind clinical trial", *American Journal of Clinical Nutrition*, vol. 103, pp. 926–933, 2016.
49. K. Kohlmann, M. Callaghan-Gillespie, J. M. Gauglitz, M. Steiner-Asiedu, K. Saalia, C. Edwards, M. J. Manary, "Alternative Ready-To-Use Therapeutic Food Yields Less Recovery Than the Standard for Treating Acute Malnutrition in Children From Ghana", *Global Health: Science and Practice*, pp. 1-12, 2019.
50. K. A. Amegovu, P. Ogwok, S. Ochola, P. Yiga, J. H. Musalima, E. Mutenyo, "Formulation of sorghum-peanut blend using linear programming for treatment of moderate acute malnutrition in Uganda", *Journal of Food Chemistry and Nutrition*, vol. 1, no. 2, pp. 67-77, 2013.
51. K. F., Michaelsen, C. Hoppe, N. Roos, P. Kaestel, M. Stougaard, L. Lauritzen, … H. Friis, "Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age", *Food and Nutrition Bulletin*, vol. 30, no. 3, pp. S343-S404, 2009.
52. Nutriset, "Plumpy'Sup, supplément nutritionnel prêt à consommer (RUSF)", Mise à jour le 29/05/2017. FC-PSUP-1426\5, 2017. nutriset@nutriset.fr-www.nutriset.fr
53. D. C. Nieman, D. E. Butterworth, C. N. Nieman, "Nutrition", *Brown Wm.C. Publishers*, Dubugue, USA, pp. 237-312, 1992.
54. M. Y. G. Shills, & V. R. Young, "Modern Nutrition in Health and Disease", In: Nieman, D.C., Butterworth D.E., and Nieman C.N., (Eds.), Nutrition. *Brown Wm. C. Publishers*, Dubugue, USA, pp. 276-282, 1992.
55. I. Rahman, S. K. Biswas, P. A .Kirkham, "Regulation of inflammation and redox signaling by dietary polyphenols", *Biochemical and Pharmacology*, vol. 72 no. 11, pp. 1439-1452, 2006.
56. T. L. Zern, and M. L. Fernandez, "Cardioprotective effects of dietary polyphenols", *Journal of Nutrition*, vol. 135, no. 10, pp. 2291-2294, 2005.
57. S. Soro, F. E. Elleing and, M. G. Koffi, E. Koffi, "Evaluation des propriétés antioxydantes et biologiques de farines infantiles à base d'igname/soja/sources végétales de minéraux", *Journal of Applied Biosciences*, vol. 80, pp. 7031-7047, 2014.
58. K. W. Disséka, "Elaboration d'aliments de complément à base de graines de sésame (*Sesamum indicum*) et de feuilles de moringa (*Moringa oleifera*): étude du potentiel nutritif et nutritionnel", Thèse de Doctorat Sciences et Technologies des Aliments, Université Nangui Abrogoua, Abidjan, Côte d'Ivoire, 145 p,2019.
59. A. C. Oche, O. P. Chudi, U. S. Terver, S. Akende, "Proximate Analysis and Formulation of Infant Food from Soybean and Cereals Obtained in Benue State, Nigeria", *International Journal of Food Sciences and Biotechnology*, vol. 2,no. 5, pp. 106-113, 2017.
60. J. Tuazon-Nartea, and G. P. Savage, "Investigation of oxalate levels in sorrel plant parts and sorrel-based products. *Food and Nutrition Sciences*, vol. 4, no. 8, pp. 838-843, 2013.
61. I. Lestienne, "Contribution à l'étude de la biodisponibilité du fer et du zinc dans le grain de mil et conditions d'amélioration dans les aliments de complément", Thèse de Doctorat Sciences des aliments, Université Montpellier II, France, 230 p,2004.
62. T. Beta, L. W. Rooney, L. T. Marovatsanga, J. R. N. Taylor, "Effect of chemical treatments on polyphenols and malt quality in sorghum", *Journal of Cereal Sciences*, vol. 31, pp. 295-302, 2000.
63. K. A. Amegovu, P. Yiga, K. K. Kuorwel, T. Chewere, "Nutrient and Anti-nutrient Profile of a Local Formula from Sorghum, Peanut, Honey and Ghee (Metu2)

for Treatment of Severe Acute Malnutrition", *Journal of Food and Research*, vol. 7, no. 2, pp. 25-34, 2018.
64. A. Duhan, B. Chauhan, D. Punia, A. C. Kapoor, "Phytic acid content of chickpea (*Cicer arietum*) and black gram (*Vigna mungo*): varietal differences and effects of domestic processing and cooking methods", *Journal of the Sciences of Food and Agriculture*, vol. 49, pp. 445-449,1989.
65. A. Duhan, N. Khetarpaul, S. Bishnoi, "Content of phytic acid and HCl-extractability of calcium, phosphorus and iron as affected by various domestic processing and cooking methods", *Food Chemitry*, vol. 78, pp. 9-14, 2002.
66. O. O. Oladunmoye, R. Akinoso, A. A. Olapade, "Evaluation of some physical-chemical properties of wheat, cassava, maize and cowpea flours for bread making", *Journal Food Quality*, vol. 33, pp. 693-708, 2010.
67. P. R. Saha, C. M. Weaver, A. C. Mason, "Mineral bioavailability in rats from intrinsically labeled whole wheat flour of various phytate levels", *Journal of Agricultural Food and Chemistry*, vol. 42, pp. 2531-2535, 1994.
68. P. Bahwere, B. Balaluka, J. Wells, C. N. Mbiribindi, K. Sadler, P. Akomo, M. Dramaix-Wilmet, S. Collins, "Cereals and pulse-based ready-to-use therapeutic food as an alternative to the standard milk- and peanut paste–based formulation for treating severe acute malnutrition: a noninferiority, individually randomized controlled efficacy clinical trial", *American Journal of Clinical Nutrition*, vol. 103, pp. 1145–1161, 2016.
69. E. R. Monsen, G. L. Hallberg, M. Layrisse, D. M. Hegsted, J. D. Cook, W. Mertz, C. A. Finch, "Estimation of available dietary iron", *American Journal of Clinical Nutrition*, vol. 31, pp. 134-141, 1978.
70. FAO/WHO, "Requirements of vitamin A, iron, folate and vitamin B12", FAO, Rome.1988.
71. L. H. Allen, and N. Ahluwahlia, "Improving iron status through diet: The application of knowledge concerning dietary iron bioavailability in human populations", USAID/OMNI, Washington DC.,1997.
72. L. Hallberg, M. Brune, L. Rossander, "Effect of ascorbic acid on iron absorption from different types of cereals", *Human Nutrition - Applied Nutrition*, vol. 40, pp. 97-113,1986.
73. D. Siegenberg, R. Baynes, T. Bothwell, B. Macfarlane, R. Lamparelli, N. Car, … F. Mayet, "Ascorbic acid prevents the dose-dependent inhibitory effects of polyphenols and phytates on nonheme-iron absorption. *American Journal of Clinical Nutrition*, vol. 53, no. 2, pp. 537-541, 1991.
74. E. S. Fordyce, R. M. Forbes, K. R. Fobbins, J. W. Erdman, "Phytate x calcium/zinc molar ratios: Are they predictive of zinc bioavailability?", *Journal of Food and Sciences*, vol. 52, pp. 440-444, 1987.

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Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for writing a good quality Medical Research Paper

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of medical research then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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ISSN 9755896