Nutritional Value and Sensory Acceptability of *M. oleifera* Fortified Finger Millet Porridge for Children with Cerebral Palsy in Nairobi County, Kenya

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Abstract

Nutritional deficiencies and other nutritional comorbidities commonly affect children with cerebral palsy. Interventions through fortification to enhance nutrient densities of foods for these groups may improve their intakes and consequently their nutritional and health status. This study was undertaken to determine the nutritional value and sensory acceptability of a finger millet porridge fortified with *Moringa oleifera* leaf powder. Standard methods approved by the Association of Official Analytical Chemists were adopted for determination of nutrient and anti-nutrient content of samples. Sensory evaluation was conducted according to the method of Larmond (1977). Statistical analysis was conducted with the aid of Statistical Package for Social Sciences software version 20. One-way analysis of variance with a post-hoc test of Least Significant Difference to separate the means was used to compare the nutrient and anti-nutrient content of samples. Independent t-test was used to test difference in mean sensory scores between fortified and control porridge. The results showed that *M. oleifera* leaf powder had significantly higher contents of protein and β-carotene, which were the target nutrients for fortification of the fermented finger millet flour. Fermentation reduced the levels of anti-nutrients in finger millet flour. Fortification of the fermented finger millet flour with *M. oleifera* leaf powder at the ratio of 9:1 significantly improved the protein and β-carotene content of the fortified flour and did not significantly affect the sensory acceptability of the fortified porridge. This study confirmed the potential for *M. oleifera* as suitable fortificant in finger millet porridge formulations to improve both protein and β-carotene intake in target populations

Keywords: acceptability, β-carotene, cerebral palsy, finger millet, *Moringa oleifera*, protein

1. Introduction

Undernutrition, growth failure, and micronutrient deficiencies are nutritional comorbidities that commonly affect neurologically impaired children (Marchand and Motil, 2006). Appropriate nutritional interventions may improve linear growth, weight, health, and quality of life and reduce the frequency of hospitalization in these children (Marchand and Motil, 2006). According to Boateng et al. (2019), improving the quality of diets is one of the most cost-effective strategies for improving public health and reducing morbidity and mortality in many populations more so in children with cerebral palsy where feeding difficulties compromise their food intake thereby leading to nutritional deficiencies.

One of the main ways to provide additional nutrients to populations at risk of nutrient deficiencies is fortification (Boateng et al., 2019). Food fortification is an important nutrition intervention to fight micronutrient deficiencies and to reduce their incidence in many populations (Rowe, 2020). In particular, food-to-food fortification is an approach that uses an interesting local resource (plant or animal) to fortify another food. This approach consists of selecting and associating foods (a common staple and a fortifying food) in such a way as to optimize the nutritional value and enhance nutrient intake (Ohanenye et al., 2021; Tenye et al., 2020). The fortifying agent is selected based on some criteria e.g. it must be readily available, and easily accessible besides containing useful

amounts of micronutrients. The rate of fortification varies considerably, between 1% and 50% depending on the compatibility of the vehicle (the staple food) and the fortificant (Chadare et al., 2019). For both classical food fortification and food-to-food fortification, the main objective is to improve the nutritional quality of the fortified food without compromising its sensory acceptability (Chadare et al., 2019; Johnson, Mannar and Ranum, 2004). The Food and Agricultural Organization is currently promoting the use of indigenous and/or underutilized crops readily found in various localities as an economically sustainable strategy for enhancing food security and addressing common deficiencies in local populations.

Although finger millet is currently categorized as a neglected and underutilized species (Opole, 2019), it remains a staple food and therefore a source of food security for a large segment of low-income population groups in East Africa and a suitable vehicle for food-to food fortification interventions in the region (Gull, Jan, Nayik, Prasad & Kumar, 2014; Sircar and Chadra, 2019). Finger millet is also reported to be rich in important nutrients including carbohydrates, proteins, calcium, iron and zinc which coupled with its excellent storage qualities makes it a popular complementary food (Dinesh, Kumar and Singh, 2014). In many local communities, finger millet porridge is a common food for both children and adults. Finger millet's nutritive value is however compromised by the presence of anti-nutrients such as phytates, phenols and tannins, as well as poor digestibility of millet proteins, which militate against its utilization in human nutrition particularly in neurologically impaired (NI) children. Processing technologies such as compositing, fermentation, malting, etc. can mitigate the effects of these anti-nutrients and significantly improve the bioavailability of finger millet proteins and minerals (Nkhata, Ayua, Kamau & Shingiro, 2018; Si, Cg, 2020; Dayakar, Malleshi, Annor & Patil, 2016). In particular, fermentation improves flavor and nutritional properties and helps to preserve food products (Ramashia et al., 2019).

M. oleifera has also been receiving increasing attention from the food processing industries owing to its high content of important nutrients including proteins, minerals such as calcium and iron and vitamins such as carotenoids and vitamin C as reported by some studies (Boetang et al., 2018; Fuglie & Sreeia, 2011; Ndubuaku et al., 2015; Witt, 2013). Cereal processors have shown interest in the enrichment of their products with a low cost, local source of vitamins and minerals such as *M. oleifera* leaf powder (Singh et al., 2018). A study by Isingoma et al. (2018) reported that enrichment of millet flour with *M. oleifera* leaf powder (MoLP) improved the nutritional value of the porridge. According to Shija, Rumisha, Oriyo, Kilima and Massaga (2019), the nutritional potential in *M. oleifera* leaf powder makes it an important ingredient in improving nutrient diversification in complementary food for children. The leaves provide significant quantities of the key nutrients including calcium, iron, vitamin A (carotenoid) and vitamin C. In addition, *M. oleifera* leaves are rich in all essential amino acids. On the other hand, moringa tree is a tropical plant grows well on all type of soils, although humus-rich forest soil is the most ideal. Although it is affected by water stress, the plant tolerates drought conditions (Agbogidi & Ilondu, 2012).

Food acceptance plays a crucial role in the success of nutrition interventions that seek to introduce new food commodities (Nicklaus, 2011). For a nutrition intervention to be successful, the majority of the target population must accept and consume the food commodities in quantities sufficient to improve their nutritional health (Miller and Welch, 2013). Given the unique sensory characteristics (color, taste, and odor) of MoLP, sensory acceptability is a critical factor when designing dietary interventions incorporating MoLP (Boeteng, Nyarko, Asante & Steiner-Asiedu, 2018). This study assessed the nutritional value and sensory acceptability of *M. oleifera*- fortified finger millet porridge formulated for nutritional intervention among children with cerebral palsy in Nairobi, Kenya.

2. Materials and Methods

2.1 Production of Fermented Finger Millet Flour

Finger millet was purchased from the local markets and sorted for quality following the East African Standards Specifications for Finger Millet grains (EAS 758:2011 ICS 67.060). The grains were then milled to obtain flour. The flour was mixed with warm water at the ratio of 1:2 respectively, then covered with a muslin cloth and incubated at 25-30°C for 48hours (Sharma & Kapoor, 1996). The water was drained and the paste spread into sheets then dried in the oven for 12hours at 115 ℃.

2.2 Production M. oleifera Leaf Powder

Fresh *M. oleifera* leaves were cleaned with clean water to remove dirt and other impurities. They were then washed in 1% saline solution (NaCl) for 3 minutes to remove microbes logged on the surfaces followed by rinsing in clean water to remove the saline solution. Afterward, the leaves were blanched in steam for 3 minutes to inactivate enzymes and preserve color followed by cooling in ice water for 5 minutes and spreading out on

racks for 20 minutes to drain off the water. The leaves were then solar dried on racks at 50° C to a uniform moisture content of 7.5% followed by milling into a powder using a kitchen blender. The dried M. oleifera leaf powder was packaged in translucent polythene bags and stored at room temperature until used for nutrient analysis and porridge fortification.

2.3 Formulation of Fortified Flour

The Pearson square method of Wagner and Stanton (2009) was used to determine the proportion for mixing which was established at the ratio of 9:1, FFmf to MoLP respectively. The product formulation was aimed at providing adequate protein which was the targeted primary nutrient.

2.4 Preparation of Porridges

Standard recipes were followed during the preparation of the control and experimental porridge samples. One hundred grams of flour and 1000 mL of clean water were weighed in sufuria (sauce pan) followed by stirring to form a homogenous slurry. Exactly 25 g of sugar was added to the slurry to improve the taste while 10g of oil was added to enhance vitamin A absorption. The slurry was cooked for 10 minutes in medium heat while stirring continuously to form a thick gruel and then kept in thermo-flasks ready to be served to the sensory panelists. samples of the porridges were coded and cooled to 40 ^{0}C before each exercise of sensory evaluation. Laboratory analysis samples were let to cool to room temperature before storing under deep freezing at -20 ^{0}C. Nutrient analysis of the porridge samples was conducted within a span of 3 weeks from the preparation date.

2.5 Analysis of Nutrients

2.5.1 Determination of Nutrient Content of M. Oleifera Leaf Powder, Fermented and Unfermented Millet Flour and the M. olefifera- Fortified Millet Flour

The content of protein, fat, moisture, and ash was determined by the methods of the Association of Official Analytical Chemists [AOAC, 2005]. The carbohydrate content was calculated by difference method as described by FAO (2010).

2.5.2 Determination of Moisture

Moisture content was determined using the oven drying as described by AOAC (2005) in method number 925.10. Samples (5g) were placed into pre-weighed dry crucibles then heated in a hot air oven (Gellenkamp, UK) at 105 ^{0}C for 3 hours. Samples were cooled and weighed after every 30 minutes until weight change was not recorded after 3 successive measurements. Measurements were taken using an electronic balance (NBY323/64: Avery East Africa). The dried samples' final weights were taken and the moisture content of the samples was calculated as:

$$\% \ \text{MC} = ((\text{Wt of crucible} + \text{fresh sample}) - (\text{wt of cruble} + \text{dry sample})) \ / \ (\text{wt of fresh sample}) \times 10 \quad (1)$$

2.5.3 Crude Fat Analysis

Crude fat was determined by soxhlet extraction as outlined by AOAC (2005) in method number 920.39. One gram dried sample was weighed into an extraction thimble and covered with absorbent cotton. 50 mL solvent (petroleum ether) was be added to a pre-weighed flask. Both thimble and flask were attached to the extraction unit. The sample was then subjected to extraction with solvent for 30 minutes followed by rinsing for 1.5 hrs. Afterward, the solvent was vacuum evaporated from the flask to the condensing column. Extracted fat in the flask was placed in an oven at 110 ℃ for 1 hr to evaporate the solvent. The weight of extracted lipid was determined by subtracting the weight of the empty flask from the total weight of flask + fat after drying. Crude fat was calculated using the following formula:

$$\% \ \text{Crude fat (db)} = (\text{Extracted fat} \ / \ \text{dried sample weight}) \ \text{x} \ 100 \quad (2)$$

2.5.5 Crude Protein Analysis

The amount of protein was determined by -Kjeldahl digestion method as described by AOAC (2005) in method number 920.87. One gram of each sample was weighed and digested in concentrated sulphuric acid with one Kjeldahl tablet before neutralizing using 40% sodium hydroxide and distilling. The resulting solution was then titrated with 0.1N hydrochloric acid using a mixed indicator (methyl red and bromocresol green). The percentage of nitrogen (N) was then determined by the equation

$$\% \ nitrogen = (S - B) \times N \times 0.014 \times D \times 100/W \times V \quad (3)$$

Where D = dilution factor, N= Normality of acid, T= titre value = (S-B), W = weight of sample, S= Volume of acid required to titrate sample B= Volume of acid required to titrate blank 0.014 = constant value. Crude protein was obtained by multiplying the corresponding total nitrogen (N) content by a conversion factor of 6.25. Thus:

Crude protein (%) = %Nitrogen $\times$ 6.25

2.5.6 Ash Content Determination

The total content of ash in samples was determined by dry ashing according to method number 923.03 by AOAC (2005). Samples (5g) were weighed in dry crucibles and carbonized on a hot plate then heated on a muffle furnace (Nerberthem: model; L9/11/C6, Germany) for 8 hours at 600 ^{0}C after which they were cooled in a desiccator and weighed. The % ash content was calculated by the difference in weight after cooling the samples to ambient temperatures. The% ash content in the sample was calculated as follows:

$$Crude\ ash\% = \ (w\_1 - w\_2)/(Weight\ of\ sample) \times 100 \qquad (4)$$

Where: w_1 = weight of empty crucible, and w_2 = weight of crucible with ash.

2.74 Determination of Total Carbohydrate

The total percentage carbohydrate content in the flour samples was determined by the difference method This was calculated as described by Sultana et al. (2017):

% carbohydrate = 100 – (% moisture +% crude fiber +%protein +% lipid +% ash)

2.5.8 Vitamin A

Vitamin A content of samples was determined as β – carotene (its precursor in plants) using UV–VIS Spectrophotoscopy method. For the extraction of β - carotene, 50 mL of acetone–hexane mixture containing 0.1% BHT was added to 5g sample and the mixture was shaken for 10 minutes, centrifuged and decanted to a separating funnel. The supernatant was saponified by the addition of 25 mL of 0.5M methanolic potassium hydroxide, before shaking and allowing to settle for 30 minutes and then washing with 100 mL portions of distilled water. The aqueous layer was discarded continuously. The extract was then dried by filtering over anhydrous sodium sulphate. The filtrate was concentrated in a rotary evaporator at 45 ℃ and reconstituted in methanol to 50 mL. Different concentrations of standard solution were prepared using 95% UV β – carotene. A stock solution of (100 μg/mL) was made by dissolving 0.01 g of β - carotene standard into 10 mL hexane, which was then increased to 100 mL. The working standard solution was used to prepare standard solutions of various concentrations. The absorbance (A) of each concentration was measured using the UV–Vis Spectroscopy at a wavelength of 545nm (Gupta et al., 2005).

2.5.9 Determination of Tannins

Tannin in samples was extracted with 50% methanol and quantified using Folin Denis Reagent as described by (Swain, 1979). Sample extract (1 mm) was pipetted into a 50-mL volumetric flask, before adding distilled water (20 mL), Folin-Denis reagent (2.5 mL), and 17% Na_2CO_3 (10 mL) and mixing. The mixture was then made up to mark with distilled water, and thoroughly mixed, then allowed to stand for 20 min until a bluish-green color developed. Standard solutions of tannic acid in the range of 0–10 ppm were treated in a similar manner as the 1 mL sample above and was used to obtain a standard curve. The absorbances of the tannic acid standard solutions, as well as samples, was obtained using UV-VIS spectrophotometer at 760 nm.

$$Tannin(mg\ /\ g) = ([A]\_s - A\_(b\ ) - intercept))/(Slope \times d \times W) \times 1 \qquad (5)$$

Where A_s is the sample absorbance, A_b is the blank absorbance, d is the density of the solution (0.791 g/mL), W is the weight of the sample in gram, and 1 is the aliquot.

2.5.10 Determination of Phytates

The Wheeler and Ferrel (1971) indirect colorimetric method was employed for phytate content determination. Five grams of the sample was extracted with 3% trichloro acetic acid. The phytates were precipitated as ferric phytate and converted to ferric hydroxide and soluble sodium phytate by adding sodium hydroxide. The precipitate was dissolved in hot 3.2 N HNO and the absorbance read immediately at 480 nm. The standard solution was prepared from Fe (NO3)3 and the iron content was extrapolated from a Fe (NO)3 standard curve. The phytate concentration was calculated from the iron concentration determined for the samples, assuming a 4:6 iron:phosphorus molecular ratio.

2.5.11 Determination of Total Phenolic Compounds

The total phenolic compounds were determined according to the Folin–Ciocalteu colorimetric method using gallic acid as the standard as described by Horvat et al. (2020). Absorbance was measured by spectrophotometer (Hitachi, Tokyo, Japan) at 765 nm The results were quantified using external calibration and expressed as μg of gallic acid equivalent (GAE) per g of dry matter.

2.5.12 Determination of Oxalate Content

Oxalate was determined according to AOAC (2005) method. One gram of the sample was weighed in a 100-mL conical flask. The 70 mL of H2SO4 (3M) was added and the solution stirred intermittently with a magnetic stirrer for about 1 hour, followed by filtering using Whatman No. 1 filter paper. The sample filtrate /extract (25 mL) was collected and then titrated against hot (80–90 ℃) 0.1 N KMnO4 solution to the point where a faint pink coloration appears and persists for at least 30 sec. The oxalate concentration in each sample was calculated: 1 mL 0.1 permanganate = 0.006303 g oxalate.

2.6 Sensory Analysis

The sensory acceptability of the porridge samples was tested among a group of 50 untrained panelists consisting of randomly selected caregivers of children with CP in the reproductive age 15-49 years who had signed an informed consent form. The sample size was based on the recommendation for affective consumer tests which is 50 -100 (Civille et al., 2018; Gacula, 2018). The study objectives and the sensory evaluation procedure were explained to the panelists and they were informed about the importance of giving honest and independent opinions after sampling the porridges. The method of Larmond (1977) was employed during the sensory evaluation. Each of the panelists was provided with two coded porridge samples in own tables in a spacious, well-lit and well-ventilated room and required to rate each attribute on a five-point facial hedonic scale (1 = extremely dislike; 5 = extremely like), The tables were placed wide apart such that it was not possible for panelists to communicate with each other in order to enhance the independence of opinions among panelists. Each panelist was given two sensory questionnaires, one questionnaire for each coded sample. The exercise was conducted during the morning hours between 9.00am and 12.00 noon. Serving of samples was done at a uniform temperature (45^{0}C) and equal quantities (30 mL) of each coded sample were provided for each panelist. Each panelist was provided with a glass of lukewarm water for rinsing the mouth in between samples. The panelists were instructed to pause for a minute from tasting and scoring one sample before proceeding to the next. The researcher was available throughout the sensory evaluation sessions to assist the study participants when required. Scores were averaged to obtain an overall rating for each attribute including overall acceptability.

2.7 Statistical Analysis

Data analysis was conducted with the aid of Statistical Package for Social Sciences (SPSS) software version 20. One-way analysis of variance (ANOVA) with a post-hoc test of Least Significant Difference (LSD) to separate the means was used to compare the nutrient and anti-nutrient content of samples. Sensory acceptability was described in terms of mean hedonic scores for the different sensory test parameters. Independent t-test was used to test difference in scores between fortified and control porridge.

3. Results

3.1 Nutrient Content of Porridge Flour Samples

Except for carbohydrates, the MoLP flour had the highest contents of both proximate and β-carotene, followed by the fortified flour while the fermented finger millet flour had the least contents of the nutrient (Table 1). The initial ANOVA results showed that significant differences existed in both the proximate and β-carotene content between the flour samples (p-value < 0.001). Post hoc analysis revealed that the MoLP had significantly higher content of protein, crude fat, ash and β-carotene than the finger millet flour samples except for carbohydrates. Furthermore, except for carbohydrate, which improved, fermentation of the finger millet flour compromised both its proximate and β-carotene content but not significantly (p>0.05). The fortified porridge flour had significantly higher contents (p<0.05) of both proximate and β-carotene than the non-fortified flour samples except carbohydrates (Table 1).

Table 1. Nutrient Contents of Samples (Mean values, dwb; N=3 ±SE)

Nutrient	Descriptives				ANOVA test		
	Nutrient content (Mean ±SE); N=3				df	f-value	p-value
	FFmF	UFmF	Mo-FFmF	MoLP			
Moisture (%)	10.03±1.12	14.77 ±0.69	9.26 ±0.24	11.61±1.07	3,8		<0.001
Protein (%)	8.98 ±12.9[a]	10.18 ±0.62[a]	13.76±1.19[b]	20.05 ±0.62[c]	3,8	25,652	<0.001
Total Fat (%)	0.7 ±0.06[a]	2.00 ±0.58[a]	9.10 ±0.35[b]	14.70 ±0.92[c]	3,8	130.104	<0.001
Carbohydrates (%)	77.0 ±1.76[a]	67.41±0.53[ab]	68.83 ±1.14[b]	19.90 ±1.96[c]	3,8	314.9	<0.001
Ash (%)	2.62 ±0.05[a]	3.06 ±0.06[a]	3.29 ±0.12[a]	13.74 ±0.71[b]	3,8	223.977	<0.001
β-carotene (mg/100)	1.08 ±0.02[a]	1.19 ±0.00[a]	1.42 ±0.00[b]	12.59 ±0.08[c]	3,8	18929.579	<0.001

Key

- FFmF ∞ Fermented Finger Millet Flour; UFmF ∞ Unfermented Finger Millet Flour; Mo-FFmF ∞ *Moringa oleifera* Fortified Fermented Finger Millet Flour; MoLP ∞ *Moringa oleifera* Leaf Powder; SE-Standard Error
- Superscripts with different letters in the same row show values that are significantly different at $\acute{\alpha}$ = 0.05

3.2 Anti-nutrient Content of Porridge Flour Samples

The MoLP had the highest content of anti-nutrients followed by the unfermented finger millet flour while the fermented finger millet flour samples had the least content of anti-nutrients (Table 2). The initial ANOVA test results showed the differences in the content of anti-nutrients between the flour samples were significant (p < 0.001). Post-hoc (LSD) analysis revealed that MoLP had significantly higher levels of anti-nutrients than both the fermented and unfermented finger millet flour samples. Furthermore, fermentation significantly reduced the levels of anti-nutrients in the finger millet flour (p<0.05). Fortification of the fermented finger millet flour with MoLP also resulted in a significant increase in the levels of anti-nutrients but the levels were still much lower compared to the unfermented finger millet flour (Table 2).

Table 2. Anti-nutrients' composition of samples (Mean values, N=3 ± SE

Anti-nutrient	Descriptives				ANOVA test		
	Content of anti-nutrients in mg/100g (Mean ±SE), N=3				df	f-value	p-value
	FFmF	UFmF	Mo-FFmF	MoLP			
Tannins	182.29 ±10.2[a]	893.00 ±0.04[b]	292.03 ±0.01[c]	1835.4 ±4.39[d]	3,8	139.583	<0.001
Phytates	185.96 ±0.00[a]	606.67 ±0.00[b]	295.33 ±0.02[c]	1054.00 ±0.06[d]	3,8	87.780	<0.001
Oxalates	27.57 ±0.00[a]	62.53.0 ±0.00[b]	305.60 ±0.00[c]	1680.89 ±0.00[d]	3,8	225328.7	<0.001
Total phenols	1029.53±0.0[a]	2716.33 ±0.07[b]	1546.00±0.02[c]	10598.33 ±0.8[d]	3,8	2503.12	<0.001

Key

- FFmF ∞ Fermented Finger Millet Flour; UFmF ∞ Unfermented Finger Millet Flour; Mo-FFmF ∞ *Moringa oleifera* Fortified Fermented Finger Millet Flour; MoLP ∞ *Moringa oleifera* Leaf Powder; SE-Standard Error
- Superscripts with different letters in the same row show values that are significantly different at $\acute{\alpha}$ = 0.05

3.3 Sensory Acceptability

The means score per attribute for both porridge samples showed that both the porridge samples were acceptable [i.e. a score above 4.0 which represented moderate like] (Table 3). The overall sensory rating of the two porridge samples was not significantly different [t (52) = -0.212; p = 0.883] although the control porridge had a better overall acceptability score than the fortified porridge (Table 3).

Table 3. Hedonic scores for color, texture, taste and overall acceptability on fortified porridge and Non-fortified porridge

Test variable	Mean hedonic scores for porridge from (Mean±SD)		Statistics		
	Fortified Flour (Mo-FFmF)	Non-fortified Flour (FFmF)	t-value	df	p-value
Color	4.74 ±0.45	4.37 ±0.49	2.896	52	0.006*
Texture	4.63 ±0.49	4.44 ±0.58	1.268	52	0.210
Taste	4.44 ±0.51	4.67 ±0.47	-1.537	52	0.130
Overall acceptability	4.52 ±0.75	4.56 ±0.51	-0.212	52	0.833

*Significant at p<0.05

4. Discussion

4.1 Nutrient Contents of Porridge Flours

The target/focus nutrients for fortification of the finger millet flour in this study were protein and β-carotene. The results show that MoLP had significantly higher contents of both protein and β-carotene than the Finger millet flour sample. Furthermore, the contents of these nutrients in the fortified flour (Mo-FFmF) were significantly improved as compared to their content in both the non-fortified flour samples (FFmF and UFmF). The results

point to the potential of MoLP as a suitable fortificant for the finger millet flour with regard to the two target nutrients (protein and β-carotene) and are consistent with the findings of a review conducted by Boateng et al. (2019). The aforementioned authors estimated the minimum amount of *M. oleifera* leaf powder (MLP) to be added to a complementary food blend in order to realize significant improvements in its nutritional value to be about 10%. Besides, MoLP had significantly higher content of ash than the finger millet flours. High ash content is an indication that the *M oleifera* is also rich in minerals, a fact which is well established in the literature. Inadequate intake of micronutrients is recognized as an important contributor to the global burden of disease through increased rates of illness and mortality from infectious diseases and of disability such as mental impairment (Black et al., 2008). Deficiencies of vitamin A, among others, in children are the most devastating in terms of impaired development and mortality (Hall, Drake & Bundy, 2001).

The protein content value of 20.05 ± 0.62% obtained in the current study for *M. oleifera* leaf powder is in agreement with that reported by Ntila (2017) who reported a value of 20.42%. Kayi (2013), reported crude protein content in dried *M. oleifera* leaves to range from 16.2% to 30.3% while Sahay et al. (2017) reported protein content of *M. oleifera* leaves to be 23.78%, while Isitua et al. (2015) reported 24.3% and 11.5% protein and ash respectively in MoLP. Both findings are within the range of current results. A more recent study by Rauf et al. (2020) reported a protein and ash content of 27.9% and 10.8 % respectively, with the reported protein content value being slightly higher than that observed in the current study. while Olugboyega and Oluyemisi (2016) reported 15.04% crude protein content and 9.85% ash content on MoLP.

The β-carotene content values of *M. oleifera* reported in the literature vary widely with 5.23mg /100g being reported by Sengey et al. (2013), 37.8mg/100g by Sahay et al. (2017), 13.56 mg /100g by Makkar and Becker (1997) and 18.4mg/100g by Chan Yee (2018). The current study value of 12.59 mg/100g for β carotene falls within this literature range. Current findings of 1.19mg/100g β-carotene content of finger millet, are below the 6.0mg/100g reported by Ramashia et al. (2019).

The moringa-fortified flour showed significant improvements in both its protein and β-carotene content relative to the non-fortified finger millet flour samples. This indicates its potential as a nutritious porridge flour that could mitigate protein and vitamin A deficiencies in children with cerebral palsy who often suffer risk of inadequate intake of the two nutrients owing their challenges in feeding.

4.2 Anti-nutrient Content of Flour Samples

In the current study, *M. oleifera* leaf powder showed a significantly higher content of anti-nutrients than the finger millet flour samples. There is a wide variation of the levels of anti-nutrients reported in literature for both *M. oleifera* and finger millet. Reported values for phytate content in *M. oleifera* vary between 42.7 to 3500mg/100g; those of tannin levels range from 374 to 6480mg/100g while those of total phenols vary between 1200 to 4831 mg/100g (Devisetti et al., 2016; Leone et al., 2015; Oladeji et al., 2017; Uchenna et al., 2015). Current study values for contents of phytates (1054.00 ± 0.06) and tannins (1835.4 ± 4.39) in *M. oleifera* fall within the range of values reported in literature while that of total phenols are higher. On the other hand, the anti-nutrient levels reported in literature for finger millet vary between 0.679 - 851.4 mg/100g for phytates, 0.301 - 989mg/100g for tannins and 0.91 – 680mg/100 for total phenols (Abubakar et al., 2015; Arjun et al., 2014; Samtiya et al., 2020; Singh et al., 2018; Siwela et al., 2007). Our findings for both phytates and tannins are within this range while values for total phenols are higher. The levels of anti-nutrients in plants and crops are influenced by a number of factors including geographical regions, farming practices and method of analysis. Our findings for oxalate content of finger millet are within the range of 21-270 mg/100g reported in literature (Chanhan & Sarita, 2018; Ravindran et al., 1991) while the findings for oxalate content in Moringa oleifera are close to those reported in several studies) (Stevens et al., 2016; Agbogidi et al., 2012; Shiriki et al., 2015).

In the current study, fermentation of the finger millet flour was observed to reduce the levels of anti-nutrients significantly with reductions of 79.6%, 69.3%, 55.9% and 62.1% realized for tannins, phytates, oxalic acid and total phenols respectively. Findings from previous studies on the effect of fermentation on the levels of anti-nutrients in foods vary widely. A study by Raboy (2000) reported a decrease in 49.2% and 66.5% phytic acid after germination and fermentation, respectively. Antony and Chandra (1998) reported that fermentation of finger millet flour using endogenous grain microflora showed a significant reduction of phytates by 20% and tannins by 52% at the end of 24 hours. There was a simultaneous increase in mineral availability (calcium-20%, phosphorous-26%, iron-27% and zinc-26%) (Pragya, 2020). Fermentation of cereal flours is a scientifically proven strategy that reduces the levels of anti-nutritional factors in foods and enhances the bioavailability of certain micronutrients (Saleh et al., 2013; Subastri et al., 2015).

The high levels of the anti-nutrients in *M. oleifera* pose a possible bottleneck in the nutritional applications of the

plant. The anti-nutritional factors can affect the digestibility of proteins, can have an effect on carbohydrates' digestion and may inactivate vitamins (Adamu et al., 2018). When ingested, tannins form complexes with proteins, which cause the inactivation of many digestive enzymes and decrease protein digestibility (Joye, 2019; Su & Chen, 2020). Phytic acid, is the main phosphorus store in mature seeds of finger millet. It forms complexes with metal ions and inhibits their absorption and is reportedly a major factor behind the deficiency of zinc (Samtiya et al., 2020; Raboy, 2000; Pragya, 2012). Phenolic compounds decrease the bioavailability of amino acids, cause loss of body weight, loss of appetite, breathing problems and cardiac complications (Samtiya et al., 2020), but most of them are destroyed during processing treatments. One limitation of the fortified porridge was with regard to its oxalate content, which was increased. above its levels in both fermented and unfermented finger millet flours, however, this could be mitigated variation of the process to introduce fermentation after blending of flour. Fermentation of the already blended flour, as opposed to the pure finger millet flour, could be necessary to achieve a greater reduction of antinutrients in the fortified porridge.

4.3 Sensory Acceptability of the M. oleifera Fortified Finger Millet Porridge

The results for sensory evaluation showed that fortification of the finger millet flour with MoLP at the ratio of 9:1 respectively did not significantly affect both taste and overall acceptability of the porridge. Other studies have reported an inverse relationship between *M. oleifera* addition and sensory acceptability of porridges (Boateng et al., 2019; Olaitan et al., 2014) with taste/flavor being the sensory property mostly affected (Ntila et al., 2019; Oyeyinka et al., 2018). Contrary to the current study finding that the fortified porridge had a better rating for color, other previous studies reported a negative effect of *M. oleifera* fortification on the color rating of porridges attributing the resultant greenish color of porridges due to *M. oleifera* addition as one of the underlying reasons for decreased sensory acceptability of foods formulated with *M. oleifera* (Boateng et al., 2019). Sensory acceptance of a food product is an important indicator of the actual use of the product, i.e., whether the product will be purchased and consumed. However nutritious a product is, if not accepted and consumed by the ultimate beneficiaries, the technological development goes in vain (Boateng et al., 2018; Rajeswari et al., 2013). Nekitising (2018) has proposed the repeated taste exposure strategy to promote positive acceptance over time. For instance, some studies reported that children increased their intake of vegetables after five exposures (Holley et al., 2017)**.**

5. Conclusion

The results of the current study showed that *M. oleifera* leaves are highly nutritious and suitable agent for food-to-food fortification of local staples to enhance their nutrient density. The study has also revealed that fortifying the finger millet porridge with MoLP at the rate of 10% significantly improved its nutrient content particularly the protein and β-carotene content without significantly compromising its sensory acceptability. Consumption of the fortified flour porridge by children with CP could therefore improve the protein and vitamin A status in this population who are at risk of protein and vitamin A deficiency due to the feeding challenges that characterize their condition. There is however a need to explore more product formulation and processing methods, in order to enhance both the sensory acceptability and nutritional potential of *Moringa*-based foods.

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