Sokoine University of Agriculture

MSc Dissertation

Development and Acceptability of Moringa Fortified Porridge for Children Aged 1-2 Years

Salha Yustus Selemani

May 2024

DEVELOPMENT AND ACCEPTABILITY OF MORINGA FORTIFIED PORRIDGE FOR CHILDREN AGED 1-2 YEARS

Dissertation submitted to Sokoine University of Agriculture in Fulfillment of the Requirements for Master Degree in Food Quality and Safety Assurance

By

Salha Yustus Selemani

Supervisors

Dr. Abdulsudi Issa Zackaria
Prof. Lucy Mlipano Chove

Department of Food science and Agro-processing
School of Engineering and Technology
Sokoine University of Agriculture, Morogoro, Tanzania

May 2024

EXTENDED ABSTRACT

BACKGROUND INFORMATION

Malnutrition is a significant public health problem in Tanzania, particularly among children under the age of five. Chronic under nutrition under the age of five is associated with less schooling, late entry into starting school, and between 22 to 45% less income throughout a lifetime. Inappropriate complementary feeding practices are linked with high incidences of under nutrition among infants and young children in Tanzania. Complementary feeding practices in Tanzania are suboptimal as they do not meet the four WHO-recommended complementary feeding indicators.

Complementary feeding is the process of introducing solid foods to an infant's diet while continuing to breastfeed. It is a critical period for infant growth and development, and appropriate complementary feeding practices are essential for optimal growth and development. Inappropriate complementary feeding practices, such as late introduction of complementary foods, low meal frequency, and low dietary diversity, are frequent in low- and middle-income countries (LMICs). A study conducted in Tanzania found that improving complementary feeding practices is feasible in Tanzania given the renewed focus on child nutrition in the country. Child nutrition policy interventions should target all mothers, particularly mothers from low socioeconomic backgrounds and those with limited access to health services to maximize results. Another study found that inappropriate complementary feeding practices have a significant effect on the nutritional status of children aged 6-24 months in Tanzania.

The current study set out to produce and explore the potential for nutrient-dense, palatable, and affordable complementary food products made from nutritious locally available underutilized crops like *Moringa oleifera* combined with cereals and other non-cereal starchy foods.

METHODOLOGY

Flours made from cleaned and powdered pearl millet, dry dates, Orange fleshed sweet potato (OFSP), and *Moringa* leaves were mixed in different ratios to form seven products to meet the nutritional requirement for young children aged 1-2 years old. These flour samples were analyzed for proximate composition based on AOAC guidelines. The contents for specific minerals (iron, zinc, and calcium) was analyzed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Whereas UV spectroscopy was used to determine pro-Vitamin A content in the samples. Additionally, the samples were subjected to functional quality tests to establish their viscosity, bulk density, and water absorption capability. Porridge was prepared from the 7 samples stated above. Consumer acceptability and quantitative descriptive analysis (QDA) tests were conducted on the porridge samples. The Statistical Package for Social Sciences (SPSS-version 25) was used to evaluate the test results. A one-way analysis of variance (ANOVA) test was run, with significant differences identified at the 5% level ($p<0.05$). The mean ± SD of the duplicate data was used to express all results. A PCA Biplot was performed to show the correlation between the samples and characteristics.

RESULTS AND DISCUSSION

The objective of this study was to formulate a highly nutritious and tasty porridge for children aged between 1-2 years. Seven different blends were produced based on specific ratios that were calculated according to Recommended Daily Allowances (RDA) for children aged 1-2 years. Each ingredient used in the study contributed differently to both the functional and sensory qualities of the porridge. Notably, Orange-fleshed sweet potato and Dates generally enhanced the sensory quality of the porridge samples. The ratios included 90:2.5:7.5 [PmMD1], 95:2.5:2.5 [PmMD2], 88:3:9 [PmMD3] for Pearl millet grain flour, *Moringa* leaf powder, and dates, respectively. Likewise, ratios of 95.5:2:2.5 [PmMP1], 88:2:10 [PmMP2] and 95:2.5:2.5 [PmMP3] were used for Pearl millet grain flour, Moringa leaf powder, and Orange-fleshed sweet potato. A control sample was prepared by blending Pearl millet, Dates, and Orange-fleshed sweet potato in a ratio of 50:15:35 [PmDP]. The results showed that the flour's nutritional composition, measured on a dry weight basis, was as follows: iron, zinc, and calcium contents ranged between 4.5-6.3, 1.46-1.81, 183-240 mg/100g, respectively; pro-vitamin A content was 308-497 µg/110g; crude fiber: 2.6-3.3 g/100g; ash: 1.9-2.13 g/100g; crude fat: 0.66-1.38 g/100g; carbohydrates: 73-77 g/100g and 346-352 g/100g energy. Significant variations ($p<0.05$) were observed in bulk density and viscosity due to differences in the quantities of Orange-fleshed sweet potato and Dates used, but no significant difference ($p>0.05$) was noted in water absorption capacity between these samples. Sensory evaluation studies recorded significant differences in aroma, taste, color, and overall acceptability ($p<0.05$) in all samples. The sample PmDP was the most preferred in terms of color, whereas PmMP2 scored the highest score in aroma, taste, and overall acceptability. Quantitative descriptive analysis revealed no significant differences ($p>0.05$) in color, aroma, thickness, and grittiness between samples. However, there was a significant difference ($p<0.05$) in the intensity of sweetness among the samples, with mean values ranging from1.9 to 4.2. The control sample [PmDP] scored the highest in sweetness intensity due to the presence of naturally sweet Orange-fleshed sweet potato and Dates. A PCA bi-plot illustrated the relationship between the samples and their attributes.

It was found that adding Moringa to the supplemental food significantly increased its nutritional value. However, adding more than 3% Moringa in porridge formulations resulted in higher values than the RDA, which would limit its use in the stated age group. The functional qualities are important in influencing qualities related to storage, transportation, and distribution in addition to sensory appeal. The acceptance of the samples was enhanced by the addition of dates and orange-fleshed sweet potatoes. The most -

liked sample, PmMP2 (88% pearl millet:2% Moringa leaf powder:10% orange fleshed sweet potato), was therefore recommended for toddlers between the ages of one and two years.

IKISIRI KUU

TAARIFA ZA MSINGI

Kutokuwa na lishe kamili ni hali inayotokea wakati mwili hupata kiasi kidogo cha virutubishi vinavyohitajika kufanya kazi vizuri. Hali hii inaweza kusababishwa na upungufu wa chakula au lishe isiyosawazika inayokosa virutubisho muhimu kama protini, vitamin, na madini. Kutokuwa na lishe kamili kunaweza kusababisha mfumo wa kinga dhaifu, ukuaji usio wa kawaida, na matatizo mengine ya afya

Kutokuwa na lishe kamili ni tatizo kubwa la afya ya umma nchini Tanzania, haswa kwa watoto walio chini ya miaka mitano. Kulingana na utafiti, utapiamlo wa muda mrefu katika umri wa chini ya miaka mitano unahusishwa na kupata elimu kidogo, kuanza shule kwa kuchelewa, na kupungua kwa kipato kati ya 22% hadi 45% katika maisha . Mienendo isiyo sahihi ya kutoa vyakula vya kuongeza kwa watoto inahusishwa na viwango vikubwa vya utapiamlo miongoni mwa watoto wachanga na watoto wadogo nchini Tanzania. Mienendo ya kutoa vyakula vya kuongeza nchini Tanzania ina mapungufu kwani haijatimiza viashiria vinne vilivyopendekezwa na WHO.

Kutoa vyakula vya kuongeza ni mchakato wa kuingiza vyakula kwenye lishe ya mtoto wakati bado wananyonya maziwa ya mama. Ni kipindi muhimu kwa ukuaji na maendeleo ya mtoto, na mienendo sahihi ya kutoa vyakula vya kuongeza ni muhimu kwa ukuaji na maendeleo bora. Mienendo isiyo sahihi ya kutoa vyakula vya kuongeza, kama vile kuanzisha vyakula vya kuongeza kwa watoto kwa kuchelewa, kuwa na mzunguko mdogo wa milo, na kutokuwa na aina mbalimbali ya vyakula, mara nyingi hutokea katika nchi za kipato cha chini na kati). Utafiti uliofanywa nchini Tanzania uligundua kuwa kuboresha mienendo ya kutoa vyakula vya kuongeza kunawezekana Tanzania kutokana na kipaumbele kipya kinachowekwa katika lishe ya watoto nchini. Sera za lishe ya watoto zinapaswa kuwalenga akina mama wote, hasa akina mama walio katika mazingira ya kipato cha chini na wale ambao hawana upatikanaji wa huduma za afya ili kupata matokeo mazuri zaidi. Utafiti mwingine uligundua kuwa mienendo isiyo sahihi ya kutoa vyakula vya kuongeza ina athari kubwa kwenye hali ya lishe ya watoto wenye umri wa kati ya miezi 6 hadi 24 nchini Tanzania.

Utafiti wa sasa ulianzisha kuzalisha na kuchunguza uwezekano wa bidhaa za vyakula vya kuongeza zenye virutubishi vingi, ladha nzuri, na bei nafuu kutokana na mazao yanayopatikana kwa wingi, yenye afya, na ambayo hayatumiwi vya kutosha kama vile majani ya Mlonge yakichanganywa na nafaka na vyakula vyenye wanga visivyo vya nafaka.

NJIA

Kufuatana na mwongozo wa WHO/UNICEF, unga uliotengenezwa kutoka kwa ulezi na unga wa mtama uliosafishwa, tende kavu, kiazi kitamu cha njano, na majani ya Mlonge yalichanganywa kwa uwiano tofauti wa saba ili kukidhi mahitaji ya lishe ya watoto wadogo (miaka 1-2). Sampuli za unga huu zilipimwa katika maabara kwa kutumia vipimo vya kina, ambavyo huangalia nishati, nyuzinyuzi, jivu, mafuta, protini, na wanga. Vipimo hivi vilifanywa kwa kutumia mwongozo wa AOAC. Kiwango cha chuma, zinki, na kalsiamu katika sampuli kilichunguzwa kwa kutumia ICP-OES kwa ajili ya uchambuzi wa madini. Uspektroskopia wa UV ulitumika kuamua kiasi cha Vitamini A kilichopo. Aidha, sampuli zilifanyiwa vipimo kazi ili kuanzisha unono wao, kipimo cha uzito wa wingi, na uwezo wa kunyonya maji. Kwa kuongezea, vipimo vya kukubalika kwa watumiaji na uchambuzi wa maelezo wa kiasi (QDA) vilifanywa kwa sampuli za uji. Toleo la 25 la Programu ya Takwimu ya Kijamii (SPSS) lililitumika kuchambua matokeo ya vipimo. Baada ya kipimo cha post-hoc, kipimo cha uchambuzi wa utofauti wa moja kwa moja (ANOVA) kiliratibiwa, na tofauti kubwa ziligundulika kwa kiwango cha 5% ($p<0.05$). Wastani ± SD ya data maradufu iliyotumiwa kuwasilisha matokeo yote. Biplot ya PCA iliyoonyesha uhusiano kati ya sampuli na sifa ziliumbwa kwa kutumia data ya QDA.

MATOKEO NA MAJADILIANO

Lengo la utafiti huu lilikuwa kutokeza vyakula vya watoto vyenye virutubishi vingi. Mchanganyiko tofauti ulitengenezwa kwa kuzingatia uwiano maalum: 90:2.5:7.5 [PmMD1], 95:2.5:2.5 [PmMD2], 88:3:9 [PmMD3] kwa unga wa mtama, unga wa majani ya Mlonge, na tende, mtawalia. Vilevile, uwiano wa 95.5:2:2.5 [PmMP1], 88:2:10 [PmMP2], na 95:2.5:2.5 [PmMP3] ulitumiwa kwa unga wa mtama, unga wa majani ya Mlonge, na viazi vitamu vyenye nyama ya rangi ya machungwa. Uwiano huu ulihesabiwa kwa kuzingatia Viwango vya Kila Siku Vilivyopendekezwa (RDA) kwa watoto wenye umri wa miaka 1-2. Sampuli ya kudhibiti ilipatikana kwa kuchanganya mtama, tende, na viazi vitamu vyenye nyama ya rangi ya machungwa kwa uwiano wa 50:15:35 [PmDP].

Matokeo yalionyesha kuwa utungaji wa lishe wa unga, uliopimwa kwa msingi wa uzito wa kavu, ulikuwa kama ifuatavyo: kiwango cha chuma, zinki, na kalsiamu kilikuwa kati ya 4.5-6.3, 1.46-1.81, na 183-240 mg/100g mtawalia; kiwango cha Vitamini A kilikuwa kati ya 308-497 µg/110g; nyuzinyuzi gafi: 2.6-3.3 g/100g; jivu: 1.9-2.13 g/100g; mafuta gafi: 0.66-1.38 g/100g; wanga: 73-77 g/100g na nishati: 346-352 g/100g. Tofauti kubwa ($p<0.05$) zilionekana katika wiani wa wingi na unono kutokana na tofauti katika kiasi cha viazi vitamu vyenye nyama ya rangi ya machungwa na tende, lakini hakuna tofauti kubwa ($p>0.05$) zilizoonekana katika uwezo wa kunyonya maji. Katika tathmini ya hisia, tofauti kubwa ($p<0.05$) zilionekana katika sampuli zote katika sifa za hisia kama harufu, ladha, rangi, na kukubalika kwa ujumla. Sampuli ya PmDP ilikuwa maarufu zaidi kwa rangi, wakati PmMP2 ilipata alama za juu katika harufu, ladha, na kukubalika kwa ujumla. Uchambuzi maelezo wa kiasi ulifanywa kudhibitisha uwingi wa sifa kama rangi, harufu, utamu, unono, na kubanduka, ukiashiria hakuna tofauti kubwa ($p>0.05$) katika uwingi wa rangi, harufu, unene, na kubanduka. Hata hivyo, kulikuwa na tofauti kubwa ($p<0.05$) katika uwingi wa utamu kati ya sampuli, na wastani wa viwango vikirangi kutoka 4.2 hadi 1.9. Sampuli ya kudhibiti [PmDP] ilipata alama kubwa zaidi kwa utamu kutokana na uwepo wa viazi vitamu vyenye nyama ya rangi ya machungwa na tende, ambazo kwa kawaida ni tamu. Biplot ya PCA ilionyesha uhusiano kati ya sampuli na sifa zao. Kila kiungo kilichotumiwa katika utafiti kilitoa mchango tofauti katika ubora wa kazi na hisia za uji. Kwa kiasi kikubwa, viazi vitamu vyenye nyama ya rangi ya machungwa na tende viliongeza ubora wa hisia wa sampuli za uji.

HITIMISHO

Kutokana na utafiti huu, imeonekana wazi kuwa kuongeza Moringa kwenye vyakula vya kuongezea kunaweza kuongeza sana maudhui ya virutubishi. Hata hivyo, ni muhimu kuzingatia kiwango cha Moringa kinachoweza kuongezwa ili kuepuka kuongezeka kupita kiasi kwa virutubishi. Aidha, mambo ya kazi na ubora wa hisia ni muhimu katika kubuni vyakula hivi, kuzingatia uhifadhi, usafirishaji, na kukubalika kwa watumiaji.

Uchunguzi umefunua kuwa kuongeza tende na viazi vitamu vyenye nyama ya rangi ya machungwa kulisaidia sana katika kuongeza kukubalika kwa sampuli. Sampuli ya PmMP2 iliyopendwa zaidi imependekezwa kwa matumizi ya watoto wadogo kati ya umri wa mwaka mmoja na miaka mitatu. Hii inaonyesha kuwa vyakula vyenye Moringa yanaweza kuwa na jukumu kubwa katika kuboresha lishe ya watoto. Kwa ujumla, utafiti huu unaonyesha umuhimu wa kuzalisha vyakula vya watoto vyenye virutubishi bora na ladha nzuri, na inatoa mwelekeo wa jinsi ya kufikia lengo hilo kwa kutumia Moringa na viungo vingine vyenye afya.

DECLARATION

I, **SALHA YUSTUS SELEMANI**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted to any other institution.

______________________ ______________________

Selemani Salha Yustus Date

(MSc. Food Quality and Safety Assurance)

The above declaration is confirmed by;

______________________ ______________________

Dr. Abdulsudi Issa Zackaria Date

(Supervisor)

______________________ ______________________

Prof. Lucy Mlipano Chove Date

(Supervisor)

LIST OF PUBLISHED PAPERS

1. Salha, S. Y., Abdulsudi, I.-Z., & Lucy, C. M. (2023). Functional and Sensory Quality of Complementary Food Blended with Moringa Leaf Powder. *European Journal of Nutrition & Food Safety*, *15*(9), 13–24. https://doi.org/10.9734/ejnfs/2023/v15i91332

2. Selemani, S. Y., Issa-Zacharia, A., & Chove, L. M. (2023). Nutritional Evaluation of a Complementary Food Based on Dates, Millet, Orange-Fleshed Sweet Potato and Moringa Leaf Powder. *Asian Food Science Journal, 22(10),* 100–111. https://doi.org/10.9734/afsj/2023/v22i10677

COPYRIGHT

ACKNOWLEGMENTS

All the glory belongs to the almighty God who gave me a healthier condition throughout my studies up to the completion of this work. Special acknowledgment also goes to my precious mother Mwinga Mangwangi for provision of financial support and encouraging me during the course of my studies. I am indebted and greatly appreciative to my supervisor Dr. Abdulsudi Issa Zackaria and Prof. Lucy Mlipano Chove of the Department of Food Science and Agro-processing, Sokoine University of Agriculture, for their valuable time to supervise this work. I thank them for their great assistance, guidance, encouragement and advices since the development of the proposal up to the completion of this study. Kind and sincere assistance of Laboratory Technicians and for their cooperation in data collection aspect of this work is highly appreciated. Lastly, I frankly thank all my classmates, friends: V Mpalanzi, J Mremi, H Matembo and I Nyango, A. Songwe, J. Fidelis, relatives, family friends and all who in one way or the other encouraged me and helped me in achieving this work.

May God bless them abundantly.

DEDICATION

I dedicate this work to my beloved mother Mwinga Mangwangi but also my dear friend I. Nyango and friends for their constant encouragement and support during the course of my studies.

This research report is also dedicated to all mothers who face challenges in feeding their Children. Mothers whose children suffer from various diseases related to nutrient deficiency. It is an honor to face this challenge together with them and contribute a way to help solve nutrition deficiency problem in young children.

TABLE OF CONTENTS

EXTENDED ABSTRACT i
IKISIRI KUU v
DECLARATION ix
LIST OF PUBLISHED PAPERS x
COPYRIGHT xi
ACKNOWLEGMENTS xii
DEDICATION xiii
LIST OF TABLES xvi
LIST OF FIGURES xvii
LIST OF APPENDICES xviii
LIST OF ABREVIATIONS AND ACRONYMS xix

CHAPTER ONE 1
1.0 INTRODUCTION, JUSTIFICATION AND OBJECTIVES 1
1.1 Background Information 1
1.2 Problem statement and justification 3
1.3 Objectives 5
1.3.1 General objective 5
1.3.2 Specific objectives 5
1.4 Structure of the Dissertation 5
REFERENCES 6

CHAPTER TWO 13
Functional and Sensory Quality of Complementary Food Blended 13
With Moringa Leaf Powder 13

CHAPTER THREE 26
Nutritional Evaluation of a Complementary Food Based on Dates, Millet, Orange- Fleshed Sweet Potato and Moringa Leaf Powder 26

CHAPTER FOUR 39

4.0 GENERAL DISCUSSION 39
4.1 Nutritional Quality of the Porridge 39
4.2 Functional Quality of the Porridge 40
4.3 Sensory Quality of the Porridge 40
REFERENCES 42

CHAPTER FIVE 43
5.0 GENERAL CONCLUSION AND RECOMMENDATION 43
5.1 Conclusion 43
5.2 Recommendations 44

APPENDICES 46

LIST OF TABLES

PAPER 1

Table 1: Composition of complemented food from pearl millet, orange-fleshed sweet potato, date, and Moringa leaf (g/100 g) 18
Table 2: Attributes, references, and anchors developed in quantitative descriptive analysis panel training 19
Table 3: Functional properties of the porridge samples 47
Table 4: Acceptability of the Porridge samples 20
Table 5: Mean intensity scores of porridge samples by the sensory panel 23

PAPER 2

Table 1: Composition of complemented food from pearl millet, orange-fleshed sweet potato, date, and Moringa leaf (g/100 g) 30
Table 2: Proximate composition (g/100 g DM), energy (kcal/100 g) of Complementary food blended with Moringa Leaf Powder 32
Table 3: Recommended daily nutrient requirements for children aged 12-23 months 33
Table 4: Requirements for processed cereal-based foods for infants and young children 33
Table 5: Mineral Composition (mg/100g DM), Vitamin A (µg/100g) of Complementary food blended with Moringa Leaf Powder 36
Table 6: Distribution summary of nutrients in each sample obtained from 3 servings per day 36

LIST OF FIGURES

PAPER 1

Figure 1: Flowchart for the preparation of complementary food powder 18
Figure 2: Bi-plot of PCA showing an association between samples and attributes 22

PAPER 2

Figure 1: Flowchart for the preparation of complementary food powder 29
Figure 2: Flour and Powder for the complementary food ingridients 30

LIST OF APPENDICES

Appendix 1: Consumer acceptability sensory evaluation questionnaire 46
Appendix 2: Quantitative Descriptive Analysis sensory evaluation questionnaire 47
Appendix 3: Letter of Clearance from SUA 49
Appendix 4: Turnitin Originality report.. 51

LIST OF ABREVIATIONS AND ACRONYMS

ANOVA:	Analysis of Variance
AOAC:	Association of Official Analytical Collaboration
CODEX:	Codex Alimentarius Commission
EAS:	East African Standards
FAO:	Food and Agriculture Organization
g:	Grams
ICP-OES:	Inductively Coupled Plasma Optical Emission Spectroscopy
Kg:	kilograms
LMICS:	Low and Middle Income Countries
OFSP:	Orange fleshed sweet potato
TBS:	Tanzania Bureau of standards
UNICEF:	United Nations International Children's Emergency Fund
WHO:	World health Organization

CHAPTER ONE

1.0 INTRODUCTION, JUSTIFICATION AND OBJECTIVES

1.1 Background Information

Malnutrition includes both over nutrition and under nutrition which is caused by a lack of essential vitamins and minerals in the body. Under nutrition can result in being underweight, wasting, and stunting (Fernandes *et al*., 2021). With 50% of childhood mortality attributed to underlying under nutrition, malnutrition has long been linked to poverty, a poor diet, and limited access to healthcare. Malnutrition is still a major worldwide health concern where both, over nutrition and under nutrition cause and contribute to ill health (Drammeh *et al*., 2019). In Tanzania, malnutrition is one of the most significant health issue affecting babies and young children (Neufeld *et al*., 2020).mn

Ensuring toddlers receive a balanced and nutritious diet is of paramount importance in their early years. Their tendency to resist certain foods can pose a challenge in meeting their nutritional requirements for optimal growth and development (WHO, 2021). In this crucial stage of life, it becomes even more vital to introduce nutrient-rich options to their diet. This includes foods from all food groups, such as fruits, vegetables, whole grains, lean proteins, and healthy fats, as well as essential nutrients like iron, calcium, and vitamin A and D, which are essential for healthy bone development (Rondanelli *et al.,* 2021).

When considering nutrient-dense additions to a toddler's diet, Moringa leaves, known for their exceptional nutritional content, can play a significant role. Moringa leaves are rich in vital minerals like calcium, potassium, magnesium, iron, manganese, and copper, along with vitamins A, B, C, and E. Moreover, they lack anti-nutritive factors, making them easily digestible and rich in proteins (Gandji *et al.,* 2018). Incorporating Moringa leaves into a toddler's meals not only addresses their nutritional needs but also provides an excellent source of essential vitamins and minerals crucial for their physical and cognitive development (Khare *et al.,* 2022).

Moringa leaves, with their impressive nutrient profile and ease of digestion, can be a valuable addition to a toddler's diet, ensuring they receive the necessary nutrients for their overall well-being and development. This emphasizes the importance of introducing highly nutritious foods like Moringa leaves to support toddlers' growth and health during this critical phase of their lives (Kodikannath *et al.,* 2022).

Due to its positive impact on immunity, inflammation, pain, diabetes, hypertension, and various other health conditions, Moringa is commonly employed in the field of medical and healthcare. Reports indicate that Moringa is highly esteemed for its nutritional attributes. Moringa leaves can be consumed raw, boiled, or powdered; they can even be stored at room temperature for a few months without losing any nutrients (Islam *et al*., 2021). The Moringa plant, which is claimed to contain a large number of minerals and vitamins, is fed to children in various developing nations of the world in an effort to boost their immunity to various ailments. Due to its high nutritional content, Moringa leaves are added to various other products like bread, cookies, soup, and flour so as to boost their nutritional level (Giuberti *et al*., 2021).

For young children, porridge is the most popular supplemental food (Ntila *et al*., 2019). One or two kinds of cereal are included in this meal, along with other ingredients such as legumes and oilseeds. Children are first exposed to this diet at the age of six months (Gama *et al*., 2022). At this age, a youngster needs more nutrients than mother's milk can provide alone.

Toddlers, children of age 1-2 years old can sometimes be difficult to handle due to their hyperactive behavior most especially during feeding. A priority must be set to maintain a calorie intake that is sufficient to ensure adequate growth and weight gain. This also should be enriched with a good supply of minerals and vitamins from foods for the perfect health of a toddler (Gubbels *et al*., 2020). Supplementary foods are crucial for optimum growth, health, and development, since this is the time when kids are most susceptible to developmental delays, micronutrient deficiencies, and frequent illnesses,. (Ulak and Tiwari, 2020). Due to the agricultural production of Tanzania being dominated by staple crops, (mostly rice and maize), cereals make up the majority of the food provided to children which are reported to be a cause of malnutrition (Minja *et al*., 2021).

1.2 Problem statement and justification

Despite tremendous progress over the past ten years, child malnutrition is still a significant public health issue in low- and middle-income nations (Victoria *et al*., 2021). In 2020, there were 462 million underweight people, 45 million wasting children, and 149 million stunted children worldwide (Tizazu *et al*., 2022).

Child malnutrition is a serious public health issue, and Tanzania is one of the ten worst-affected countries in the world (Khamis *et al*., 2019). Nationally, 34.7% of children under the age of five suffer from chronic malnutrition (Al-Hajj *et al*.,2021). The regions of Dodoma, Ruvuma, Rukwa, Kigoma, Katavi, and Geita, and Iringa are all affected by severe stunting. Overall, Tanzania has more than 2.7 million stunted children under the age of five, which has an impact on their capacity to learn and work in the future (Lawrence *et al*., 2021). About 42% of anemia in children under the age of five is attributed to iron deficiency. Anemia has been linked to vitamin A deficiency, although its effects are more likely to result in night blindness (Mrimi *et al*., 2022).

The most common type of food given to children in Tanzania is made from pearl millet, sorghum, and maize (Kulwa *et al*., 2015). This contributes to high rates of undernutrition in infants and young because these foods are of poor micronutrient content and can't entirely satisfy children's demands (Masuke, *et al*., 2021).

Millet and sweet potato are good sources of carbohydrates and plays a crucial role in fighting against Protein energy malnutrition (PEM). There are more than 20 different varieties of millet, but pearl millet is among the most widely grown and produces more than half of the world's millet (Hanna *et al*., 2014). It is a good source of protein, minerals, and mainly carbohydrates. Nutritional and functional properties including the digestibility of millet are shown to improve by germination. Germination has been recommended as a suitable approach to addressing the malnutrition problem because it enhances the nutritional value, protein content, and digestibility of the grain, while also making it a more accessible option for regions with nutritional deficiencies (Udeh *et al*., 2017).

Sweet potato (*Ipomoea batatus L. Lam*) is a dicotyledonous plant of the family *Convolvulaceae* (Tortoe *et al*., 2010). The crop is a main source of dietary fiber and complex carbohydrates and is as well used in making industrial starch (Korada *et al*., 2010). The new variety of Orange Fleshed Sweet Potatoes (OFSP) popularity continues to grow due to its high levels of nutrients especially β-carotene. OFSP is now grown more in developing countries than any other root crop. Its promotion is good for food security and it is a nutritious food, highly recommended for alleviating vitamin A deficiency (VAD), and is an important staple food and cash tuber crop in Tanzania (Sanoussi *et al*., 2016). OFSP is of a sweet nature and hence has a masking effect on the undesirable taste and odor of products. Thus, it can be used to increase the acceptability of moringa-fortified food products (Gebretsadikan *et al.,* 2015).

The leaves of the *Moringa oleifera* plant are rich in essential elements like proteins, and minerals like zinc, calcium, iron, and vitamin A (Gandji *et al*., 2018). Consuming Moringa powder for six months raises hemoglobin levels and decreased anemia instances

(Shija *et al*., 2019). According to reports, the superfood Moringa has more calcium and iron than milk and spinach respectively (Islam *et al*., 2021). All of the necessary amino acids are abundant in these leaves. Due to its rich nutritional profile and low price, it is becoming more and more popular and used in fortifying different foods. Meals containing Moringa are reported to significantly increase the weight of severely undernourished kids (Ariesthi *et al*., 2021). Moringa is currently used as an alternative food source to fight malnutrition due to its dense nutrients (Gopalakrishnan *et al*., 2016).

The aim of this study was to develop porridge flour supplemented with Moringa that would be useful in fighting malnutrition among toddlers.

1.3 Objectives

1.3.1 General objective

Development of a nutritious, energy-dense, and acceptable supplemental porridge flour for children aged 1-2 years old).

1.3.2 Specific objectives

i. To develop a pearl millet and sweet potato porridge enriched with *Moringa oleifera* leaves.
ii. To determine the chemical quality of the porridge flour including; proximate analysis and micronutrient composition (Iron, Zinc, Calcium, and Vitamin A).
iii. To analyze the physical quality of enriched porridge (Bulk density, Viscosity and Water absorption capacity).
iv. To assess sensory quality and consumer acceptability of Moringa enriched porridge.

1.4 Structure of the Dissertation

The dissertation is organized in a published paper format. Chapter one entails the general introduction to this study. Chapter two and three presents the published papers whereas chapter four presents the general discussion and chapter five the general discussion and recommendations.

REFERENCES

Al-Hajj, N. Q., Ahmed, A. H. A., Naji, T., Alabyadh, M., & Al-Hashedi, S. A. (2021). Assessment Of the Nutritional Status of Under-Five Years (6–59 Months) Children Attending Friendship Teaching Hospital, Aden Province, Yemen. *World J. Pharm. Res*, *10*(5), 47-59.

Anderson, R. A., Conway, H. F., Pfeifer, V. F. and Griffin, E. L. (1969). Roll and extrusion. Cooking of grain sorghum grits. *Cereal Science Today, 14*(11), 372- 376.

AOAC (1999). Official Methods of Analysis.16th Edition. Association of Official Analytical Chemists, Washington, D. C, USA. 54pp.

Ariesthi, K. D., Pattypeilohy, A., Fitri, H. N., & Paulus, A. Y. (2021). Additional Feeding Based on Local Food to Improve the Nutritional Status of Toddlers. *KEMAS: Journal Kesehatan Masyarakat*, *17*(1), 67-74.

Bello-Schünemann, J., & Moyer, J. D. (2018). Structural pressures and political instability: Trajectories for sub-Saharan Africa.

Berhanu, Z., Alemu, T., & Argaw, D. (2019). Predictors of inappropriate complementary feeding practice among children aged 6 to 23 months in Wonago District, South Ethiopia, 2017; case control study. *BMC pediatrics*, *19*(1), 1-13

Brahmachari, K., Sarkar, S., Santra, D. K., & Maitra, S. (2019). Millet for food and nutritional security in drought-prone and red laterite region of Eastern India. *Int J Plant Soil Sci*, *26*(6), 1-7.

Civille, G., Stone, H., Derthmer, A., & Eggert, J. (2018). Sensory Evaluation Guide for Testing Food and Beverage Products. Sensory Evaluation Division. *Food Technology [Internet]. Institute of Food Technologists.*

Ding, Q. B., Ainsworth, P., Tucker, G. and Marson, H. (2005). The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. *Journal of Food Engineering, 66*, 283-289.

Drammeh, W., Hamid, N. A., & Rohana, A. J. (2019). Determinants of household food insecurity and its association with child malnutrition in Sub-Saharan Africa: A review of the literature. *Current Research in Nutrition and Food Science Journal*, *7*(3), 610-623.

Gacula, M. C. (Ed.). (2004). Descriptive sensory analysis in practice. Trumbull, Connecticut, USA: *Food & Nutrition Press*.

Gama, A. P., Matumba, L., Munthali, J., Namaumbo, S., Chimbaza, M., Ngoma, T., & Fungo, R. (2022). Acceptability of orange corn-common bean as an alternative to corn-soybean complementary porridge in Malawi. *Journal of Food Science*, *87*(7), 3163-3172

Gandji, K., Chadare, F. J., Idohou, R., Salako, V. K., Assogbadjo, A. E., & Kakaï, R. G. (2018). Status and utilisation of Moringa oleifera Lam: A review. *African Crop Science Journal*, *26*(1), 137-156.

Gebretsadikan, T. M., Bultosa, G., Forsido, S. F., & Astatkie, T. (2015). Nutritional quality and acceptability of sweet potato–soybean–moringa composite porridge. *Nutrition & Food Science*.

Giuberti, G., Bresciani, A., Cervini, M., Frustace, A., & Marti, A. (2021). Moringa oleifera L. leaf powder as ingredient in gluten-free biscuits: nutritional and physicochemical characteristics. *European Food Research and Technology*, *247*(3), 687-694

Gokhale, J. S., Lele, S. S., & Ananthanarayan, L. (2021). Indian Traditional Foods and Diets: Combining Traditional Wisdom with Modern Science of Nutraceuticals and Functional Foods. In *Nutrition, Food and Diet in Ageing and Longevity* (pp. 357-392). Springer, Cham.

Gopalakrishnan, L., Doriya, K., and Kumar, D. S. (2016). Moringa oleifera: a review on nutritive importance and its medicinal application. *Food Science. Human Well*. 5, 49–56.

Gowele, V. F., Kinabo, J., Jumbe, T., Rybak, C., & Stuetz, W. (2021). High prevalence of stunting and anaemia is associated with multiple micronutrient deficiencies in school children of small-scale farmers from Chamwino and Kilosa districts, Tanzania. *Nutrients*, *13*(5), 1576.

Gubbels, J. S., Gerards, S. M., & Kremers, S. P. (2020). The association of parenting practices with toddlers' dietary intake and BMI, and the moderating role of general parenting and child temperament. *Public Health Nutrition*, *23*(14), 2521-2529.

Hanna, W. W., Baltensperger, D. D., & Seetharam, A. (2004). Pearl millet and other millets. *Warm‐season (C4) grasses*, *45*, 537-560)..

Ho, P. (2015). Statistical methods and tools for analyzing sensory food texture: Modifying food texture. *Food science, Technology and Nutrition*, 45-87. Woodhead Publishing Series.

Islam, Z., Islam, S. M., Hossen, F., Mahtab-ul-Islam, K., Hasan, M., & Karim, R. (2021). Moringa oleifera is a prominent source of nutrients with potential health benefits. *International Journal of Food Science*, *2021*.

Khamis, A. G., Mwanri, A. W., Ntwenya, J. E., & Kreppel, K. (2019). The influence of dietary diversity on the nutritional status of children between 6 and 23 months of age in Tanzania. *BMC pediatrics*, *19*(1), 1-9.

Khare, A., Samudre, S., & Arora, A. (2022). Sneak-peek into iron deficiency anemia in India: The need for food-based interventions and enhancing iron bioavailability. *Food Research International*, 111927.

Kodikannath, J., & Gregory, A. Y. (2022). *The Parent's Complete Guide to Ayurveda: Principles, Practices, and Recipes for Happy, Healthy Kids*. Shambhala Publications.

Korada, R. R., Nasakar, S. K., Palaniswami, M. S. and Ray, R. C. (2010). Management of sweet potato weevil Cylas formicarius (Fab.): An overview. *Journal of Root Crops, 36: 14-26*

Lucy Lawrence, S. (2021). *Predicting stunting status among children under five years: The case study of Tanzania* (Doctoral dissertation, University of Rwanda).

Malave, L., van Dijk, M. T., & Anacker, C. (2022). Early life adversity shapes neural circuit function during sensitive postnatal developmental periods. *Translational Psychiatry*, *12*(1), 1-14.

Masuke, R., Msuya, S. E., Mahande, J. M., Diarz, E. J., Stray-Pedersen, B., Jahanpour, O., & Mgongo, M. (2021). Effect of inappropriate complementary feeding practices on the nutritional status of children aged 6-24 months in urban Moshi, Northern Tanzania: Cohort study. *PloS one*, *16*(5),

Mosha, D., Canavan, C. R., Bellows, A. L., Blakstad, M. M., Noor, R. A., Masanja, H., ... & Fawzi, W. (2018). The impact of integrated nutrition-sensitive interventions on nutrition and health of children and women in rural Tanzania: study protocol for a cluster-randomized controlled trial. *BMC nutrition*, *4*(1), 1-8.

Mrimi, E. C., Palmeirim, M. S., Minja, E. G., Long, K. Z., & Keiser, J. (2022). Malnutrition, anemia, micronutrient deficiency and parasitic infections among schoolchildren in rural Tanzania. *PLoS neglected tropical diseases*, *16*(3).

Nduhukire, T., Atwine, D., Rachel, L., & Byonanebye, J. E. (2020). Predictors of in-hospital mortality among under-five children with severe acute malnutrition in South-Western Uganda. *Plos one*, *15*(6).

Nefale, F. E., & Mashau, M. E. (2018). Effect of germination period on the physicochemical, functional and sensory properties of finger millet flour and porridge. *Asian Journal of Applied Sciences*, *6*(5).

Neufeld, L. M., Beal, T., Larson, L. M., & Cattaneo, F. D. (2020). Global landscape of malnutrition in infants and young children. *Global Landscape of Nutrition Challenges in Infants and Children*, *93*, 1-14.

Nkhata, S. G., Ayua, E., Kamau, E. H., & Shingiro, J. B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food science & nutrition*, *6*(8), 2446-2458.

Ntila, S., Ndhlala, A. R., Siwela, M., Kolanisi, U., & Abdelgadir, H. (2019). Acceptability of a moringa-added complementary soft porridge to caregivers in Hammanskraal, Gauteng province and Lebowakgomo, Limpopo province, South Africa. *South African Journal of Clinical Nutrition*, *32*(3), 27-33.

Obadina, A., Ishola, I. O., Adekoya, I. O., Soares, A. G., de Carvalho, C. W. P. & Barboza, H. T. (2016). Nutritional and Physico-chemical properties of flour from native and roasted whole grain pearl millet (Pennisetum glaucum [L.] R. Br.). *Journal of Cereal Science*, *70,* 247–252

Oke, E. K., Adeyeye, S. A. O., & Olorode, O. O. (2022). Complementary Foods and Its Processing Methods: A Review. *Croatian Journal of Food Science and Technology*, *14*(1), 39-51.

Oladiran, D. A., & Emmambux, N. M. (2022). Locally available african complementary foods: nutritional limitations and processing technologies to improve nutritional quality—a review. *Food Reviews International*, *38*(5), 1033-1063.

Olaitan, N. I., Eke, M. O., Uja, E. M., & Oja, E. A. (2014). Quality evaluation of complementary food formulated from Moringa Oleifera leaf powder and pearl millet (Pennisetum Glaucum) flour. *Int J Eng Sci*, *3*(11), 59-63.

Olson, M. E. (2017). Moringa frequently asked questions. A*cta Hort. 1158,* 19–32.

Onwuka, G. I. 2005. Food Analysis and Instrumentation. Theory and Practice. Naphtali Prints. Surulere Lagos Nigeria. pp133 – 137

Peydayesh, M., Bagnani, M., Soon, W. L., & Mezzenga, R. (2022). Turning food protein waste into Sustainable Technologies. *Chemical Reviews*..

Pratap, A., Gupta, S. K., Kumar, J., & Solanki, R. K. (2012). Soybean. In *Technological Innovations in Major World Oil Crops, Volume 1* (pp. 293-321). Springer, New York.

Rahman, M. S., Mushfiquee, M., Masud, M. S., & Howlader, T. (2019). Association between malnutrition and anemia in under-five children and women of reproductive age: Evidence from Bangladesh Demographic and Health Survey 2011. *PloS one*, *14*(7),

Rani, S., Singh, R., Sehrawat, R., Kaur, B.P. & Upadhyay, A. (2018). Pearl millet processing: a review. *Nutrition & Food Science*, 48 (1), 30–44

Rondanelli, M., Faliva, M. A., Barrile, G. C., Cavioni, A., Mansueto, F., Mazzola, G., ... & Peroni, G. (2021). Nutrition, physical activity, and dietary supplementation to prevent bone mineral density loss: a food pyramid. Nutrients, 14(1), 74.

Saithalavi, K. M., Bhasin, A., & Yaqoob, M. (2021). Impact of sprouting on physicochemical and nutritional properties of sorghum: a review. *Journal of Food Measurement and Characterization*, *15*(5), 4190-4204.

Saleem, H., Sadaqat, H. A., & Razzaq, H. (2022). Sunflower, soybean, safflower and sesame: the power of 4 in nutrition. *J Nutr Health Food Eng*, *12*(1), 23-25.

Sanoussi, A. F., Dansi, A., Ahissou, H., Adebowale, A., Sanni, L. O., Orobiyi, A., Dansi, M., Azokpota, P. and Sanni, A. (2016). Possibilities of sweet potato (Ipomoea batatas) L. Lam value chain upgrading as revealed by physico-chemical composition of ten elite's landraces of Benin. *African Journal of Biotechnology*, *15*(13), 481-489

Santos, W. M. D., de Souza, M. L., Nóbrega, F. P., de Sousa, A. L. M. D., De França, E. J., Rolim, L. A., & Rolim Neto, P. J. (2022). A Review of Analytical Methods for Calcium Salts and Cholecalciferol in Dietary Supplements. *Critical Reviews in Analytical Chemistry*, *52*(4), 697-711.

Shija, A. E., Rumisha, S. F., Oriyo, N. M., Kilima, S. P., & Massaga, J. J. (2019). Effect of Moringa Oleifera leaf powder supplementation on reducing anemia in children below two years in Kisarawe District, Tanzania. *Food science & nutrition*, *7*(8), 2584-2594.

Tesha, N., Tungu, M., Kagaigai, A., Yohana, B., & Paulo, H. A. (2022). The paradox of food production, consumption, poverty and malnutrition in Tanzania: an ecological study design. *F1000Research*, *11*(32), 32

Thakur, A., Sharma, V., & Thakur, A. (2019). An overview of anti-nutritional factors in food. *Int. J. Chem. Stud*, *7*(1), 2472-2479

Thermo-electron Company. (2011). Viscometer 2plus (type 399-0200) user manual. Karlsruhe, Germany

Tizazu, W., Laillou, A., Hailu, B. A., Chitekwe, S., & Baye, K. (2022). Complementary feeding and food-group level inequality among Ethiopian children 6–23 months of age (2011–2019). *Maternal & Child Nutrition*, e13375.)

Tortoe, C., Obodai, M. and Amoa-Awua, W. (2010). Microbial deterioration of white variety sweetpotato (Ipomoea batatas) under different storage structures. *International Journal of Plant Biology, 1*(10), 52 pp.

UdeH, H.O., Duodu, K.G., & Jideani, A.I.O. (2017). Finger millet bioactive compounds, bioaccessibility, and potential health effects – a Review. *Czech J. Food Science*, *35*(1), 7–17.

Ulak, N., & Tiwari, K. (2020). Complementary feeding practices and it's associated factors among mothers in selected urban area of Nepal. *Asploro Journal of Biomedical and Clinical Case Reports*, *2020*(1), 1-6.

Victora, C. G., Christian, P., Vidaletti, L. P., Gatica-Domínguez, G., Menon, P., & Black, R. E. (2021). Maternal and Child Undernutrition Progress 1 Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. *Target*, *2*, 1-12.

World Health Organization. (2021). United Nations Children's Fund, World Bank Group. *Nurturing care for early childhood development: a framework for helping children survive and thrive to transform health and human potential*.

CHAPTER TWO

Functional and Sensory Quality of Complementary Food Blended With Moringa Leaf Powder

Selemani Salha Yustus[1], Dr. Abdulsudi Issa Zackaria[1], Prof. Lucy Mlipano Chove[1]*

[1]Department of Food science and Agro- processing, Sokoine University of Agriculture, Box 3006 Chuo Kikuu, Morogoro, Tanzania.

*Corresponding author, Email: salhayustus@gmail.com

[1]The material contained in this chapter has been published in *European Journal of Nutrition and food safety, 15*(9), 13–24.

https://doi.org/10.9734/ejnfs/2023/v15i91332

European Journal of Nutrition & Food Safety

Volume 15, Issue 9, Page 13-24, 2023; Article no.EJNFS.104177
ISSN: 2347-5641

Functional and Sensory Quality of Complementary Food Blended with Moringa Leaf Powder

Selemani Yustus Salha [a*], Issa-Zacharia Abdulsudi [a] and Chove Mlipano Lucy [a]

[a] *Department of Food Science and Agro-processing, School of Engineering, P.O. Box 3005, Chuo Kikuu, Morogoro, Tanzania.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2023/v15i91332

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdarticle5.com/review-history/104177

Original Research Article

Received: 26/05/2023
Accepted: 03/08/2023
Published: 23/08/2023

ABSTRACT

Functional and Sensory Quality of Complementary porridge made from Moringa Leaf Powder blended with Pearl millet, Orange-Fleshed Sweet Potato, Dateswas evaluated using standard methods. The Pearl millet grain flour, Moringa leaf powder and dates were blended in ratios of 90:2.5:7.5 [PmMD1], 95:2.5:2.5 [PmMD2], 88:3:9 [PmMD3] respectively. Also, Pearl millet grain flour, Moringa leaf powder and Orange fleshed sweet potato were blended in ratios of 95.5:2:2.5 [PmMP1], 88:2:10 [PmMP2], 95:2.5:2.5 [PmMP3], respectively. The ratios were calculated based on Recommended Daily Allowances (RDA) for children aged 1-2 years. Control sample was blended with Pearl millet, Dates and Orange fleshed sweet potato in a ratio of 50:15:35 [PmDP], respectively. A significant difference ($p<0.05$) in bulk density and viscosity were observed due to the difference in amounts of Orange fleshed sweet potato and Dates. No significant difference ($p>0.05$) in water absorption capacity was observed. Sensory evaluation showed significant difference ($p<0.05$) between all samples and in all sensory parameters namely aroma, taste, color

*Corresponding author: Email: salhayustus@gmail.com;

Salha et al.; Eur. J. Nutr. Food Saf., vol. 15, no. 9, pp. 13-24, 2023; Article no.EJNFS.104177

and overall acceptability. The sample PmDP was the most accepted in terms of colorwhereas PmMP2 was the most accepted in terms of aroma, taste and overall acceptability. Quantitative descriptive analysis was conducted to determine the intensity of color, aroma, sweetness, thickness and grittiness among the samples. No significant difference (p>0.05) in the intensity of color, aroma, thickness and grittiness. There was a significant difference in the intensity of sweetness among the samples (p<0.05) and the mean values ranged from 4.2-1.9. The control sample [PmDP] had the highest value in sweetness intensity as it contained Orange fleshed sweet potato and Dates which are both of a sweet nature. A PCA biplot was drawn to indicate the association between the samples and the attributes. All ingredients used in this study had a different contribution in the functional quality of the porridge together with the sensory quality.Orange fleshed sweet potato and Dates generally improved the sensory quality of the porridge samples.

Keywords: Complementary foods; sensory evaluation; moringa leaf powder; nutritional value.

1. INTRODUCTION

Complementary foods refer to the introduction of solid foods to children aged from 6 months and older in order to meet their daily nutritional needs [1]. This transition occurs because breastfeeding alone becomes insufficient in providing all the necessary nutrients for the child. According to the World Health Organization [2], the introduction of complementary food should be timely, meaning it should be provided when a child's energy requirements exceed what breastfeeding alone can offer. Additionally, the food should be adequate, ensuring it provides sufficient energy, protein, and micronutrients for the child's growth. Safety is another important aspect, requiring that the food is stored and prepared hygienically to ensure the child's well-being. Lastly, proper feeding practices involve offering food based on the child's signs of hunger and fullness.

Due to the importance of complementary food to young children in providing nutrients they require current research goal becomes investigating the potential to produce wholesome, available and cheap food products from the locally available crops. Food based strategies are used during the production of these foods to ensure that they have a good quality making them to be acceptable so that they can effectively provide the nutrients required by young children [3].

Composite flours are composed of a combination of cereals (such as millet, wheat, and maize), starchy roots and tubers (such as yam, cassava, and sweet potato), as well as protein-rich foods (such as soy and peanuts). It is important to note that no single cereal or legume can independently provide all the necessary nutrients to meet a child's requirements. By combining ingredients from different food groups, overall nutrition can be improved. Current understanding in the field of children's nutrition allows for the mixing or fortification of one food substance with another, resulting in a blend that possesses both nutritional quality and consumer acceptance [4].

Pearl millet (*Pennisetumglaucum*) is a highly nutritious grain crop known for its ability to withstand drought and resilience. It serves as an excellent source of carbohydrates, offering a low glycemic index. Furthermore, pearl millet is rich in dietary fiber and essential minerals, including iron, magnesium, and potassium, as well as a variety of B vitamins [5]. In Tanzania, pearl millet is commonly used as a key ingredient in the preparation of porridge for children [6].

Moringa oleifera, a highly nutritious tree, has gained recognition as a valuable reservoir of essential nutrients. It is considered as a very good supplement because of its high protein value and that encompasses all the necessary amino acids. It is also known as the miracle tree because of its diversified beneficial features, e.g., rich source of iron, 10 times more vitamins than carrots, 7 times more vitamin C than oranges, 17 times more calcium than milk, and 15 times more potassium than bananas [7]. Moringa leaves are also an excellent source of dietary fiber, high chlorophyll that supports liver health,alpha-linoleic acid (ALA) a type of omega-3 fatty acid important for heart health and brain function, phytochemicals, Anti-Inflammatory compounds like isothiocyanates potential for managing chronic inflammation, antioxidants and antimicrobial properties. Due to their nutrient density, they are employed to combat malnutrition and its associated effects [8].

Dates are the fruit produced by the date palm tree, *Phoenix dactylifera*. These fruits are

Saiha et al.; Eur. J. Nutr. Food Saf., vol. 15, no. 9, pp. 13-24, 2023; Article no.EJNFS.104177

naturally sweet and often consumed as a snack or added to different dishes to enhance their taste. Dates offer a rich source of both soluble and insoluble fiber, as well as essential minerals such as copper and potassium [9]. Moreover, they possess anti-inflammatory and anticancer properties. As a healthier option compared to refined sugars, dates are frequently used as natural sweeteners in food preparations.

Orange-fleshed sweet potato (*Ipomoea batatas*) is a type of sweet potato with vibrant and distinct orange-colored flesh. The captivating color is a result of a substantial content of *Beta-carotene*, which is crucial for promoting eye health, supporting immune function, and facilitating overall growth and development. These sweet potatoes serve as a valuable source of carbohydrates and dietary fiber. Additionally, they provide essential B vitamins and minerals, such as manganese [10]

Porridge is a common food given to infants. Pearl millet, Orange-fleshed sweet potato, Dates, and Moringa leaves can be used in preparation of porridge. Functional characteristics of porridge encompass its visual appearance, texture, consistency, viscosity, and mouthfeel, all of which contribute to the initial impression before consumption. These aspects play a significant role in determining the overall acceptance of the porridge. Factors such as cooking time, ingredients selection, and the ratio of water to ingredients directly impact the functional quality of the porridge [11]. In this particular study, a blend of Pearl millet, Orange-fleshed sweet potato, Dates, and Moringa leaves were used to produce complimentary flour for preparing porridge. Subsequently, sensory and functional quality tests were conducted on the resulting blends. The current research plays a significant role to examine the feasibility of creating highly nutritious and acceptable complementary food for young children

2. MATERIALS AND METHODS

2.1 Samples

Pearl millet and Orange fleshed sweet potato were obtained from Mawenzi market, whereas Moringa leaves were obtained from Frida homestead, Morogoro Tanzania. Dry dates were obtained from Kilombero market, in Arusha Tanzania.

2.2 Preparation of Moringa Leaf Powder (MLP)

The fresh Moringa leaves from the farm were sorted and the young and fresh leaves were selected. Damaged and diseased leaves were discarded. The leaves were washed with clean water and soaked in 1% NaCl for 5 minutes solution to kill microbes. The excess water was drained and leaves were spread out on racks for 20 minutes before being shade dried at room temperature for 4 days. A high-speed multifunctional crusher model 750A was used to grind the leaves to powder. A 500μm sieve was used to obtain a fine powder [12], [13].

2.3 Preparation of Orange-Fleshed Sweet Potato (OFSP) Flour

Sweet potatoes were washed, peeled, and chopped into 3mm thick slices. The slices were oven dried at 50° C overnight and later milled using a high-speed multifunctional crusher model 750A. A 500μm sieve was used to obtain a fine powder [14].

2.4 Germination and Preparation of Pearl Millet (Pm)

Pearl millet was sorted to remove extraneous matter and then washed to remove dust and mud. The sorted and cleaned millet was soaked in a 5 L bucket containing cold water for 10 h at room temperature. Water was drained from the millet grains and spread individually on wet muslin cloth where water was sprinkled at 6h break to stimulate the germination process. The millet grains germinated for 48 hours. The germinated millet was oven dried at 60°C for 10 h and was then ground using a hammer mill into flour. A 500μm was used to sieve germinated flour [15]. All the flour samples were kept in air-tight polyethylene bags and kept in a freezer at -10°C.

2.5 Preparation of Date Powder

Dried dates from the market were washed with clean water to remove dust. Inner seeds were also removed and the dates were kept in the oven for 12 hours at 60°C. They were then left to dry for one hour. Ahigh-speed multifunctional crusher model 750A was used to crush the dates so as to obtain a powder that was then sieved using a 500 μm [9].

2.6 Sample Formulation and Composition

The formulation and preparation of complementary food mix made from the prepared pearl millet flour, orange-fleshed sweet potato flour, date powder, and Moringa leaf powderare shown in Table 1 and Fig. 1,respectively.Combination of food sample ratios was calculated into different formulations to meet the FAO/WHO/UNICEF (1985) requirement for micronutrients for young children and infants. From this, seven samples (including the control sample) were formulated as indicated in Table 1.

Samples from Table 1 were prepared using flour and water in a proportion of 350g to 1000L they were cooked at medium heat for 15 minutes. The cooked porridge samples were kept in a thermos- flask ready for laboratory analysis and sensory evaluation [13].

2.7 Analyses

2.7.1 Bulk density

The method used for the determination of the Bulk density (BD) of the samples was described by Onwuka [16]. The bulk density of the samples was calculated by taking the ratio of sample weight in a cylinder to its volume.

Bulk Density was calculated using the formula:

$$BD\ (g/ml) = \frac{Weight of sample}{Volume of sample}$$

2.7.2 Viscosity

HAACE Viscotester 2plus (Thermo-electron company, Karlsruhe, Germany) was used to determine the viscosity of the porridge samples. Samples of 100 mL of each in duplicate were prepared for the test and porridge samples were used for the determination of viscosity.

2.7.3 Water Absorption Capacity (WAC)

Water Absorption Capacity was determined by using the method for cereals described by Anderson et al [17]. Porridge flour samples were sieved into fine flour with a particle size of 500 µm. One gram of each sample was suspended in 10mL of distilled water at room temperature (approximately 28°C) and gently stirred for 30 min then centrifuged at 3000 rpm for 10 min. The supernatant was decanted into an evaporation dish of known weight. The water absorption index was the weight of gel obtained after the removal of the supernatant per unit weight of original dry solids. The supernatant was then dried in an oven at 105°C overnight, and the weight of the dried supernatant was then recorded.

The water absorption index was calculated using the following formulae:

$$WAI(g/g) = \frac{weight of wet gel}{weight of the sample}$$

2.7.4 Sensory evaluation

Sensory evaluation wasconducted was by quantitative descriptive test (QDA)and consumer tests [18].

2.7.5 Quantitative descriptive analysis

QDA was conducted at the Department of Food Science and Technology by ten trained sensory panelists, comprising 5 males and 5 females with ages ranging from 21 to 28 years according to the method described in [19]. Panelists were trained to develop sensory descriptors and the definition of the sensory attributes. They developed a test vocabulary describing differences between samples and agreed upon 5 descriptors for color, aroma, sweetness, thickness, and grittiness attributes (Table 2). An unstructured line scale was used for rating the intensity of an attribute whereas a 5-point hedonic scale was used. The left side of the scale corresponded to the lowest intensity of each attribute (value 1) and the right side corresponded to the highest intensity (value 5).

2.7.6 Consumer test

Consumer test was carried out at SUA maternity clinic, Mazimbu Hospital,Morogoro in which 30 semi-trained panelists who were mothers, 40% aged between 16-26 and 60% aged between 26-50 years old were used. A 7- point hedonic scale was used (where 1 = dislike very much and 7 = like very much) as described by Lawless et al [19]. Panelists were instructed to rate color, aroma, flavor and overall acceptability indicating their degree of liking or disliking by indicating the number provided according to their preference.

In both tests, the samples to be tested were coded with 3-digit random numbers and served to each panelist in clean white disposable cup.A bottle of drinking water was provided for the judges to rinse their mouths after each test.

Satha et al.; Eur. J. Nutr. Food Saf., vol. 15, no. 9, pp. 13-24, 2023; Article no.EJNFS.104177

Table 1. Composition of complemented food from pearl millet, orange-fleshed sweet potato, date, and Moringa leaf (g/100 g)

Ingredients	Formulation Name	Ratios
Pearl Millet+ Moringa leaf powder+ Dates	PmMD1	90:2.5:7.5
	PmMD2	95:2.5:2.5
	PmMD3	88:3:9
Pearl Millet+ Moringa leaf powder+ Orange-fleshed sweet potato	PmMP1	95.5:2:2.5
	PmMP2	88:2:10
	PmMP3	95:2.5:2.5
Pearl Millet+ Dates + Orange- fleshed sweet potato (Control sample)	PmDP	50:15:35

Where Pm = Pearl Millet, M= Moringa Leaf, D= Dates, P= Orange fleshed sweet potatoes

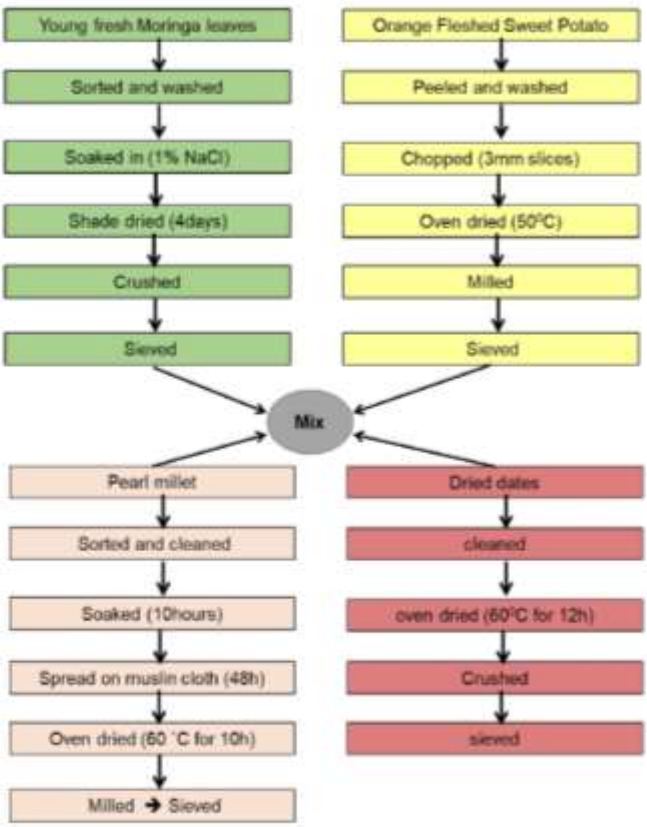


Fig. 1. Flowchart for the preparation of complementary food powder

Table 2. Attributes, references, and anchors developed in quantitative descriptive analysis panel training

Attribute	Definition	Reference	Anchors
Color	Color Intensity	Brownish	Low to High
Aroma	Aromatic	Cooked porridge aroma	Low to High
Sweetness	Sweetness Intensity	Sweetness associated with 1% sucrose solution	Not sweet to very sweet
Thickness	Porridge Viscosity	Thickness associated with honey viscosity	Not viscous to very viscous
Grittiness	Particle present in porridge	Presence of chewable particles in the porridge	Low to High

2.8 Statistical Analysis

Statistical data analysis was performed by using SPSS (Statistical package for the social Sciences Version 26.0. SPSS Inc., Chicago, IL, USA), using the one-way analysis of variance (one way ANOVA) and post hoc Turkey's Honestly Significant Difference (HSD) test at a significance level $p < 0.05$. All the data were reported using mean values of determinations ± standard deviation. Principle component analysis (PCA) was done by R software (R Core Team) to assess the association between sample and attributes.

3. RESULTS AND DISCUSSION

3.1 Functional Properties of the Porridge Samples

3.1.1 Bulk density

Bulk density is a measure of the heaviness of flour and the porosity of a product that is often affected by the particle size and density of the flour [20]. It is important for determining packaging requirements on the volume of the material, cost together with the choice of the raw material. It is also useful in material handling together with its application in wet processing in the food industry [21].The results of functional properties of the formulated porridge samples are shown in Table 3 and indicates a significant differencein Bulk density at ($p<0.05$) among the samples. The sample PmMP2 had the bulk density (1.43) followed by the control sample PmDP (1.41). In both "PmMD" and "PmMP" groups bulk density increased as the concentrations of MLP, OFSP, and dates increased. Low bulk density was probably influenced by thenature of the starch polymers which had a loose structure [22]. The lowest values were observed in the samples that contained the least amounts of dates. This trend shows the addition of other ingredients after reduction of pearl millet, increased the bulk density.

Similar observations were made by Olaitan *et al* [12]. where the bulk density of pearl millet porridge increased as the concentration of MLP increased among samples. Another study by Mahaet *al* [23]. on the effect of different supplementation levels of soybean flour on pearl millet functional properties also observed an increase in the bulk density of the flour as levels of soybean increased. Bulk density plays a crucial role in the digestibility of foods, especially for infants. Among all the samples, PmMD2 stands out as the most suitable choice due to its lowest bulk density. On the other hand, the sample with the highest bulk density (PmMP2) will take up less space per unit weight compared to the other samples, making it more commercially viable than the rest.

3.2 Water Absorption Capacity (WAC)

The water absorption capacity is the measure of the volume occupied by starch polymer after swelling in excess water. It represents the ability of a product to associate with water where water is finite [24]. Water absorption capacity provides information about the ease of a product to absorb water and therefore gives a predetermination of storage methods to be used. To avoid moisture from destroying the product airtight is often used [25].

In the current study, there was no significant difference in water absorption capacity (*$p>0.05$*)between the samples in WAC as indicated in Table 3. The values ranged from 8.48g/g to 8.69g/g. In a study by Olaitianet *al* [12]. on the Quality evaluation of Complementary

Table 3. Functional properties of the porridge samples

Sample	Bulk density	WAC(g/g)	Viscosity (dpas)
PmDP	1.41± 0.14 ^{b}	8.65±0.08^{c}	2.2 ± 0.14^{h}
PmMD1	0.60 ±0.01^{a}	8.48 ±0.20^{c}	0.72 ± 0.00^{de}
PmMD2	0.56 ±0.01^{a}	8.53±0.03^{c}	0.59 ± 0.00^{d}
PmMD3	1.41 ±0.05^{b}	8.30±0.17^{c}	0.75 ± 0.00^{em}
PmMP1	1.30 ±0.04^{b}	8.60 ±0.30^{c}	0.85 ± 0.00^{ef}
PmMP2	1.43 ±0.04^{b}	8.69 ±0.24^{c}	1.81 ± 0.00^{g}
PmMP3	1.37±0.06^{b}	8.64 ±0.36^{c}	0.96 ± 0.00^{f}

Means ± SD, values within the same column with different superscript letters are significantly different from each other (p<0.05). WAC: Water Absorption Capacity

food from MLP and pearl millet there was a significant difference in water absorption capacity among the samples. The WAC values in the study increased as the amount of MLP concentration increased. A significant difference among the samples was reported in another study by Dendeh *et al* [20], on the evaluation of stiff porridge from pearl millet and African Yam Bean, the samples that had African Yam Bean had higher values compared to the control samples. A high amount of protein and carbohydrates was mentioned as a possible cause of the results. A study by Haile *et al* [26] observed that as the amount of OFSP flour increased in the Bulla composite flour the WAC also increased. This indicated that OFSP has high WAC. Similar observations were made in this study as the samples that contained OFSP had higher values of WAC in comparison with the samples that did not contain OFSP.

3.3 Viscosity

Viscosity refers to the thickness or resistance to the flow of a fluid or semi-solid substance. Starch is the major contributor to the viscosity of any particular food. Upon heating, starch granules in the flour absorb water, swell, and release starch molecules that create a network that increases the viscosity of the porridge. Particle size, hydration, cooking time, and temperature are factors that affect viscosity.

In the current study, there was a significant difference in viscosity between the samples ($p<0.05$). The values ranged from 2.2 dpas of the control sample PmDP to 0.59 dpas of the sample PmMD2. It was observed that viscosity increased as the amount of OFSP increased. Samples that contained OFSP had higher viscosity scores in comparison with those that contained dates. This could be due to the starchy nature of OFSP that gelatinizes when heated and contributes to the viscosity of pearl millet. According to Haile *et al* [26], viscosity of Bulla composite flour increased as the amount of OFSP increased among the samples. The high-water absorption capacity of OFSP was mentioned to be a possible cause of the results. The findings from the current study are contrary to those observed by Korese [27] in which the addition of OFSP into millet flour decreased the viscosity values. This was due to a significant decrease in the amounts of millet in the flour as significant amounts of OFSP were added to the flour mixtures.

3.4 Sensory Attributes

3.4.1 Color

There was a significant difference ($p<0.05$) in color for all the samples under study as indicated in Table 4. The difference was influenced by the intense orange color of the orange-fleshed sweet potato and green color of the Moringa leaves that greatly impact the color among the samples. The scores of colors ranged from 1.8 to 6.4.

Acceptability in color in the current studywas contributed by the orange color from OFSP as it was observed that acceptability increased as the amount of OFSP increased. This is comparable to Belloet et al [10]. who formulated pearl millet flour-based cookies supplemented with mung bean and orange fleshed sweet potato floursobserved that,the acceptability of cookies improved with the inclusion of OFSP.In current study, the samples that did not contain OFSP had lower scores (Table 4) due to the unusual green color from the chlorophyll pigment of Moringa leaf powder that amplified during the drying and cooking process. It was also reported in other studies that the inclusion of Moringa leaves lead to poor acceptance of products due to the green color [12], [27] and this is in line with what was observed in current study.

Table 4. Acceptability of the Porridge samples

Samples	Color	Aroma	Taste	Overall Acceptability
PmDP	6.4 ± 0.6^{e}	4.9 ± 1.1^{g}	5.1 ± 1.1^{k}	4.7 ± 1.1^{o}
PmMD1	3.1 ± 1.2^{b}	4.1 ± 1.0^{fg}	3.1 ± 1.8^{j}	2.7 ± 1.4^{l}
PmMD2	2.5 ± 1.1^{ab}	4.1 ± 0.9^{fg}	2.7 ± 1.1^{i}	2.4 ± 0.9^{l}
PmMD3	1.8 ± 0.7^{a}	3.7 ± 1.9^{f}	3.4 ± 0.8^{j}	2.5 ± 1.8^{m}
PmMP1	4.3 ± 1.2^{c}	4.4 ± 1.4^{fg}	3.6 ± 1.7^{j}	4.0 ± 2.0^{m}
PmMP2	5.2 ± 0.8^{d}	6.4 ± 0.6^{h}	6.1 ± 1.0^{k}	5.9 ± 1.2^{no}
PmMP3	4.1 ± 1.3^{c}	4.9 ± 1.4^{g}	5.0 ± 1.6^{j}	5.1 ± 1.9^{mn}

Means ± SD, values within the same column with different superscript letters are significantly different from each other (p<0.05)

Color is one of the important attributes that leads a consumer to decide on liking of the product as it gives the very first impression. Color is used to evaluate the food's desirability and acceptability. It often triggers certain expectations on the mind of a consumer. Despite the fact that preference of color differs among people, it is important to put a high consideration in color of new products because people tend to compare the new product with those that are already in the market [18].

3.4.2 Taste

Taste or the perception of gustatory input is the most influential factor in a person's selection of a particular food as it surpasses all other attributes. The product taste can fall in one or two of the basics tastes that are sweet, salty, sour, bitter and umami. The sweet taste of the product observed in current study (Table 4) was influenced by OFSP and dates powder. The bitter taste could have been influenced by MLP that was included in some formulations.

There was a significant difference in Taste (p<0.05) among samples that were contributed by both OFSP and MLP. The higher scores observed for Orange Flesh Sweet Potato) can be attributed to its natural sweetness, which has the ability to mask the bitter taste of Moringa leaf powder as seen in PmMP2 scoring 6.1 of taste as opposed to PmMD2 which gave 2.7 taste score (Table 4). Both contained moringa leaf powder indicated as M and Orange Flesh Sweet Potato indicated as P in the formulations. This is in contrast to the samples that included dates, where the sweetening effect was not present, and in turn lead to a bitter taste due to Moringa leaf powder. A study byGebretsadikan*et al* [29]. reported that the sweet nature of OFSP allowed the incorporation of up to 7% of MLP in the porridge sample.

It was observed that dates containing samples had low rating scores. This implies that date powder did not mask the bitter taste of Moringa leaf powder resulting in overall bitter taste of the samples as it is with Orange Flesh Sweet Potato. The study by Olaitan *et al* [12]. reported the least preference for taste of porridge samples due to the inclusion of MLP. Similarobservation is reported in other study by Sengev *et al* [30]. who reported least preference in taste for moringa-supplemented wheat bread.

3.4.3 Aroma

Aroma is a fundamental segment of taste together with the general acceptability of the food prior to consumption. As indicated in Table 4, there existed a significant difference among the samples (p<0.05). The highest aroma score of 6.4 was obtained with the formulation sample (PmMP2)having the lowest amount of MLP and high amount of OFSP (2%MLP, 10%OFSP). A similar observation was reported by Gebretsadikan*et al* [29]. and Dachana *et al* [31]. for Moringa fortified biscuits and composite porridge respectively. The lowest aroma score of 3.7 was observed in the sample that contained the highest amount of MLP (3%) as observed in Table 4. Studies have reported lower ratings in complementary foods that had MLP from 5% and above [12], [28].

MLP in the porridge samples highly affected the aroma due to the leafy and herbal-like smell that it possesses when cooked. This turns out to be a turn-off to consumers as it brings a sense of medicine and not food Boateng *et al* [28].

3.4.4 Overall acceptability

There was a significant difference (p<0.05) in overall acceptance among the samples. The sample with (88%Pm: 2%MLP:10%OFSP) had the highest score (Table 4). A similar observation was made by Gebretsadikanet *al* [29], where the fortified porridges with high OFSP and/or soybean proportions with less moringa received the highest overall acceptability. The samples that contained higher amounts of MLP had the lowest scores. Studies done by Olaitan *et al* [12], Sengev *et al* [30], Dachana *et al* [31], and Hedhili *et al* [32], and reported that as the concentration of Moring leaf powder in the sample increased the overall acceptability decreased. The reason for this inverse relationship is generally the deep green color of Moring leaf powder, its leafy herbal odor, and taste that makes the consumer to be less attracted. Another reason could be due to the adoption to specific crops for porridge processing in many communities, the use of uncommon crops like Moring leaf powder has a great impact on changing their sensory attributes and this makes it hard to be accepted in short period. It can be expressed that the incorporation of Moring leaf powder in foods should be in moderation so as to increase the acceptability of products.

3.5 Quantitative Descriptive Analysis

In this study, there was no significant difference in the intensity of aroma, thickness, and grittiness together with color at ($p > 0.05$). A significant difference was only observed in sweetness among the samples. The valuesfor sweetness in ranged from (1.9 to 4.2) as seen in Table 5.

The highest score in sweetness intensity was with the control sample (50%PM+15%DT+35%OFSP) which contained higher amounts of OFSP and dates than all other samples. The sample that scored the least contained equal amounts of MLP and OFSP (95%PM+2.5%MLP+2.5%OFSP) which could be the reason that its sweetness was altered.

3.6 PCA Biplot

From Fig. 1, the bi-plot of principal component analysis shows that, PC 1 accounts for 27.8% of the variation and PC 2 accounts for 23.1% of the variations. The biplot shows that the attributes of aroma and thickness are closely associated together as they are facing the same direction. This is unlike the attributes of grittiness and sweetness that show no association with each other as each faces its own direction. The attribute of color shows no association with other attributes as it has the longest arrow drawn far away from other attributes that are shown to be a little bit closer to each other.

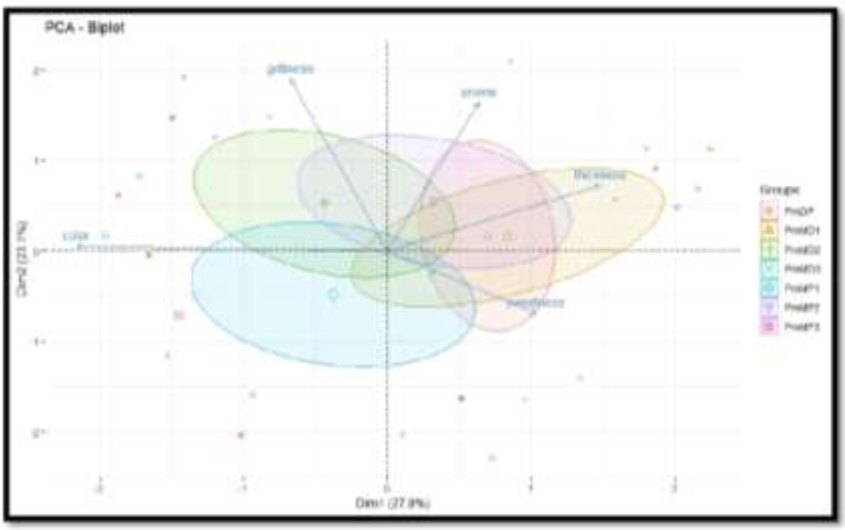


Fig. 2. Bi-plot of PCA showing an association between samples and attributes

Saha et al.; Eur. J. Nutr. Food. Saf., vol. 15, no. 9, pp. 13-24, 2023; Article no.EJNFS.104177

Table 5. Mean intensity scores of porridge samples by the sensory panel

Samples	Color	Aroma	Sweetness	Thickness	Grittiness
PmDP	1.4 ± 0.5^a	3.8 ± 0.9^b	4.2 ± 0.7^d	1.0 ± 0.0^e	2.9 ± 1.5^f
PmMD1	1.4 ± 0.5^a	3.8 ± 1.1^b	2.3 ± 0.8^c	1.2 ± 0.4^e	2.8 ± 0.6^f
PmMD2	1.6 ± 0.5^a	3.2 ± 0.9^b	2.0 ± 0.8^c	1.2 ± 0.4^e	3.0 ± 1.0^f
PmMD3	1.6 ± 0.5^a	3.1 ± 0.9^b	2.3 ± 1.1^c	1.1 ± 0.3^e	2.5 ± 0.5^f
PmMP1	1.5 ± 0.5^a	3.1 ± 0.9^b	1.9 ± 0.9^c	1.1 ± 0.3^e	2.7 ± 0.9^f
PmMP2	1.4 ± 0.5^a	3.2 ± 0.6^b	2.9 ± 1.1^{cd}	1.2 ± 0.4^e	3.0 ± 1.3^f
PmMP3	1.5 ± 0.5^a	3.1 ± 0.7^b	2.4 ± 0.8^c	1.1 ± 0.3^e	2.9 ± 1.1^f

Means ± SD, values within the same column with different superscript letters are significantly different from each other ($p<0.05$)

Key: PmDP (50%pearl millet:15%dates:35%orange fleshed sweet potato), PmMD1(90%pearl millet:2.5%Moringa leaf powder:7.5%dates), PmMD2(95%pearl millet:2.5%Moringa leaf powder:2.5%dates), PmMD3(88%pearl millet:3%Moringa leaf powder:9%dates), PmMP1(95.5%pearl millet:2%Moringa leaf powder:2.5% orange fleshed sweet potato), PmMP2(88%pearl millet:2%Moringa leaf powder:10% orange fleshed sweet potato), PmMP3(95%pearl millet:2.5%Moringa leaf powder:2.5% orange fleshed sweet potato)

The sample PmDP was strongly associated with sweetness, thickness, and aroma. The sample PmMD1 was highly associated with thickness. There was a high association between the sample PmMP2 with the attributes of grittiness, aroma, and thickness. The attribute of sweetness was slightly associated with the sample PmMP2. The sample PmMD2 is associated with all the attributes but largely with grittiness and color. The sample PmMP1 associated is the only sample that is associated highly with color while having very little association with attributes. The sample PmMD2 had the lowest preference score from consumers. It was characterized by levels of deep green color, grittiness, and aroma that was herbal and leafy from MLP that consumers did not like.

4. CONCLUSION

This study shows that functional parameters have an influence on the acceptability of product. It is therefore important to ensure that the functional parameters are considered and worked on well so as to promote acceptability of the product. Individual sensory attributes such as color, aroma and taste contributed to the overall acceptability of the product. The functional parameters not only indicate sensory acceptability but also play a crucial role in determining storage, transportation, and distribution characteristics.

The inclusion of Moringa leaf powder into the samples has shown a significant change color and taste. Its deep green color and bitter taste has affected the acceptability of the product in terms of color and taste. The addition of Dates and Orange Fleshed Sweet Potato improved the acceptability of samples. It has also shown great results in improving the functional parameters of the porridge samples. For its good nutritional profile, and sensory and functional qualities it should be used often in the development of other food products. The formulation Pm:M:P2 (88%pearl millet:2%Moringa leaf powder:10% orange fleshed sweet potato) was the most accepted sample and recommended for toddlers aging 1-3 years. Considering high nutritive profile of *Moringa oleifera* it should be added in complementary foods. Addition of Moringa in foods should be in very small amounts and added with other ingredients that could help to mask the color and bitter taste of Moringa.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Abeshu, Motuma Adimasu, Azeb Lelisa, and Bekesho Geleta. Complementary feeding: review of recommendations, feeding practices, and adequacy of

homemade complementary food preparations in developing countries–lessons from Ethiopia. Frontiers in nutrition. 2016;(4):41.
2. World Health Organization. Complementary feeding: report of the global consultation, and summary of guiding principles for complementary feeding of the breastfed child. World Health Organization; 2003.
3. Tampah-Naah, A. M., Kumi-Kyereme, A., and Amo-Adjei, J. Maternal challenges of exclusive breastfeeding and complementary feeding in Ghana. PloS one. 2019;(5)14.e0215285.
4. Mkambula, Penjani, Mduduzi NN Mbuya, Laura A. Rowe, et al. The unfinished agenda for food fortification in low-and middle-income countries: quantifying progress, gaps and potential opportunities. Nutrients.2020;12(2):354.
5. Makame, James, Henriette De Kock, and Naushad M. Emmambux. Nutrient density of common African indigenous/local complementary porridge samples. LWT.2020;133:109978.
6. Bani Hani, Nabeel, Fakher J. Aukour, and Mohammed I. Al-Qinna. Investigating the Pearl Millet (Pennisetumglaucum) as a Climate-Smart Drought-Tolerant Crop under Jordanian Arid Environments. Sustainability. 2022;(14):12249.
7. Rockwood, J. L., B. G. Anderson, and D. A. Casamatta. Potential uses of Moringa oleifera and an examination of antibiotic efficacy conferred by M. oleifera seed and leaf extracts using crude extraction techniques available to underserved indigenous populations. International Journal of Phytotherapy Research. 2013;3(2):61-71.
8. Kamran, Muhammad, ShabbirHussain, Muhammad Amin Abid, ShahzadaKhurram Syed, Muhammad Suleman et al., Phytochemical composition of moringaoleifera its nutritional and pharmacological importance. PostepyBiologiiKomorki. 2020; 47(3):321-334.
9. Hasan, MahmoodUl, AmanUllah Malik, Sajid Ali, AmnaImtiaz, AnjumMunir, WaseemAmjad, and Raheel Anwar. Modern drying techniques in fruits and vegetables to overcome postharvest losses: A review. Journal of Food Processing and Preservation. 2019;43 (12).
10. Bello, Florence A., Mercy A. Folademi, and Lawrence J. Iwok. Development of pearl millet flour-based cookies supplemented with mung bean and orange fleshed sweet potato flours.The Annals of the University Dunarea de Jos of Galati. Fascicle VI-Food Technology. 2022;(46):155-168.
11. Singh, Shubhi, Rishibha Gupta, SonamChawla, et al. Natural sources and encapsulating materials for probiotics delivery systems: Recent applications and challenges in functional food development. Frontiers in Nutrition.2022;9: 971784.
12. Olaitan, N. I., M. O. Eke, E. M. Uja, and E. A. Oja. Quality evaluation of complementary food formulated from Moringa Oleifera leaf powder and pearl millet (PennisetumGlaucum) flour. International Journal of Engineering and Science. 2014;3(11):59-63.
13. Malla, Janet Kajuju, Sophie Ochola, Irene Ogada, and Ann Munyaka. Nutritional Value and Sensory Acceptability of M. oleifera Fortified Finger Millet Porridge for Children with Cerebral Palsy in Nairobi County, Kenya. Journal of Food Research.2021;10(5):1-36.
14. Falade, Kolawole O., and Oluwakemi J. Solademi. Modelling of air drying of fresh and blanched sweet potato slices. International journal of food science & technology.2010; 45(2):278-288.
15. Nefale, Fulufhelo E., and Mpho E. Mashau. Effect of germination period on the physicochemical, functional and sensory properties of finger millet flour and porridge. Asian Journal of Applied Sciences.2018;6(5).
16. Onwuka, Gregory I. Food analysis and instrumentation: theory and practice. Napthali prints. 2005.
17. Anderson, R. A., H. F. Conway, V. F. Pfeifer, and E. L. Griffin. Roll and extrusion-cooking of grain sorghum grits. Cereal Science Today.1969;(14):372-376.
18. Meilgaard, M. C., Civille, G. V. and Carrison, B.T. Sensory Evaluation Technique, fourth edition. CRC press, Taylor and Francis group, USA. 2006. 464.
19. Lawless, Harry T., and HildegardeHeymann. Sensory evaluation of food: principles and practices. New York: Springer. 2010;2.
20. Dendegh, T. A., B. M. Yelmi, and R. A. Dendegh. Evaluation of stiff porridge (Ruamnahan) produced from composite flour blends of pearl millet

(Pennisetumglaucum) and African yam bean (Sphenostylisstenocarpa). Asian Food Science Journal. 2021;9:63-77.

21. Krishnan, Rateesh, UshaDharmaraj, R. SaiManohar, and N. G. Malleshi. Quality characteristics of biscuits prepared from finger millet seed coat based composite flour. Food chemistry.2011; 129(2):499-506.

22. Olu, Malomo, O. A. B. Ogunmoyela, O. O. Adekoyeni, O. Jimoh, S. O. Oluwajoba, and M. O. Sobanwa. Rheological and functional properties of soy-poundo yam flour. International journal of food science and nutrition engineering. 2012;2(6):101-107.

23. Maha AM, Ali, Abdullahi H. El, ElkhalifaAbdElmoneim O, MallasyLimya O, and BabikerElfadil E. Effect of different supplementation levels of soybean flour on pearl millet functional properties. Food and Nutrition Sciences. 2012.

24. Chinma, C. E., J. O. Abu, S. James, and M. Iheanacho. Chemical, functional and pasting properties of defatted starches from cowpea and soybean and application in stiff porridge preparation. Nigerian Food Journal.2012;30(2):80-88.

25. Ijarotimi, O. S. and Ashipa, F. Chemical composition, sensory and physical property of home processed weaning food based on low cost locally available food materials. International Journal of Molecular Medicine and Advance Sciences. 2005; 1(3): 213-219.

26. Haile, Abebe, Martha Geribo, and EsayasKinfe. Evaluation of porridge made from composite flour of orange-fleshed sweet potato and Enset (Bulla) flours. Agriculture and Food Sciences Research.2016;3(1):37-44.

27. Korese JK, Chikpah SK, Hensel O, Pawelzik E, Sturm B. Effect of orange-fleshed sweet potato flour particle size and degree of wheat flour substitution on physical, nutritional, textural and sensory properties of cookies. European Food Research and Technology. 2021 ;247(4):889-905.

28. Boateng, Laurene, WilheminaQuarpong, AgarthaOhemeng, Matilda Asante, and Matilda Steiner-Asiedu. Effect of complementary foods fortified with Moringa oleifera leaf powder on hemoglobin concentration and growth of infants in the Eastern Region of Ghana. Food science & nutrition. 2019;7(1):302- 311.

29. Gebretsadikan, Tirhas M., Geremew Bultosa, Sirawdink Fikreyesus Forsido, and TessemaAstatkie. Nutritional quality and acceptability of sweet potato–soybean–moringa composite porridge. Nutrition & Food Science. 2015; 45(6):845-858.

30. Sengev, Abraham I., Joseph O. Abu, and Dick I. Gernah. Effect of Moringa oleifera leaf powder supplementation on some quality characteristics of wheat bread. Food and nutrition sciences.2013; 4(3):270.

31. Dachana, K. B., Jyotsna Rajiv, D. Indrani, and JamunaPrakash. Effect of dried moringa (Moringaoleifera lam) leaves on rheological, microstructural, nutritional, textural and organoleptic characteristics of cookies. Journal of Food Quality. 2010; 33(5):660-677.

32. Hedhili, Amel, Samuel Lubbers, Elias Bou-Maroun, Francine Griffon, Babatope Ebenezer Akinyemi, Florence Husson, and Dominique Valentin. Moringa Oleifera supplemented biscuits: Nutritional values and consumer segmentation. South African Journal of Botany. 2021;138:406-414.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/104177

CHAPTER THREE

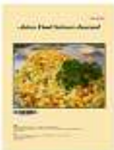
Nutritional Evaluation of a Complementary Food Based on Dates, Millet, Orange- Fleshed Sweet Potato and Moringa Leaf Powder

Selemani Salha Yustus [1], Dr. Abdulsudi Issa Zackaria[1], Prof. Lucy Mlipano Chove[1]*

[1]Department of Food science and Agro- processing, Sokoine University of Agriculture, Box 3006 Chuo Kikuu, Morogoro, Tanzania.

*Corresponding author, Email: salhayustus@gmail.com

[1]The material contained in this chapter has been published In the *Asian Food Science Journal, 22(10), 100–111*.
https://doi.org/10.9734/afsj/2023/v22i10677



Asian Food Science Journal

Volume 22, Issue 10, Page 100-111, 2023; Article no.AFSJ.106620
ISSN: 2581-7752

Nutritional Evaluation of a Complementary Food Based on Dates, Millet, Orange-Fleshed Sweet Potato and Moringa Leaf Powder

Salha Yustus Selemani [a*], Abdulsudi Issa-Zacharia [a] and Lucy Mlipano Chove [a]

[a] *Department of Food Science and Agro-processing, School of Engineering and Technology, Sokoine University of Agriculture, P.O. Box 3006, Chuo Kikuu, Morogoro, Tanzania.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2023/v22i10677

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/106620

Original Research Article

Received: 14/07/2023
Accepted: 21/09/2023
Published: 18/10/2023

ABSTRACT

The aim of this study was to formulate highly nutritious infant foods. The nutritional quality of a complementary porridge based on pearl millet, orange-fleshed sweet potato, dates and mixed with Moringa leaf powder was assessed using standard methods. A total of 7 formulations were produced, with compositional proportions calculated on the basis of recommended daily allowances (RDAs) for children aged 1-2 years. The linear regression method was used to combine the samples into different formulations to meet FAO/WHO/UNICEF requirements. The results obtained revealed that the nutritional composition of the flour on a dry weight basis was as follows: crude fiber: 2.6-3.3 g/100g, ash: 1.9-2.13 g/100g, crude fat: 0.66-1.38 g/100g, crude protein: 8.34-11.07 g/100g, carbohydrates: 73-77 g/100g and 346-352 g/100g energy. Iron, zinc and calcium contents

*Corresponding author: Email: salhayustus@gmail.com, mangwangisali@gmail.com;

were 4.5-6.3, 1.46-1.81, 183-240mg/100g respectively, and vitamin A content was 308-497 µg/110g. The incorporation of Moringa leaf powder improved the nutritional quality of the supplementary feed.

Keywords: Complementary food; moringa leaves; micronutrients; recommended daily allowance.

1. INTRODUCTION

Child malnutrition remains a pressing issue worldwide, particularly affecting children under the age of 5, with a significant number of affected children residing in developing countries [1]. The problem of malnutrition often arises in infants during or after the introduction of complementary foods, contributing significantly to the high prevalence of malnutrition in children below the age of 5 [2,3]. According to these studies, a majority of infants are introduced to cereal-based complementary foods well before the recommended age of 6 months or, in some cases; they do not receive these foods until they reach their second year of age.

One of the main causes of death among children and pregnant mothers or nursing mothers is malnutrition, which has permanent impacts on health in underdeveloped nations. Iron, zinc, iodine and vitamin A deficiency-related protein-energy malnutrition disorders have also been a problem to young children [4].

According to Mosha *et al.* [3], Tanzanian traditional supplementary foods are based on starchy staples, typically cereals such as maize, rice, sorghum, and finger millet as well as non-cereals such as cassava, sweet potatoes, yams, bananas, and plantains. Unfortunately however, such diets are typically provided without enough supplementation with high quality protein sources [5]. These foods are widely available, inexpensive, and therefore accessible to most rural residents who are lysine deficient [6]. The primary cause of the widespread protein energy malnutrition that affects babies and young children is an overdependence on these starchy sources of protein.

Children need nutrient-rich diet that is high in vitamins, minerals, proteins, and carbohydrates for a healthy growth. These are essential for newborns and young children's healthy development and for the treatment of disorders brought on by a poor diet, such as malnutrition, which has long been recognized as a significant nutritional issue in developing nations [6]. After six months, it is appropriate to introduce complementary foods, which provide additional nutrition to meet all the growing child's needs, when breast milk alone is no longer sufficient to provide enough nutrients. In recent years inadequate child feeding procedures, a shortage of complementary foods of sufficient quantity and quality, and high rates of infections, have contributed to health and growth problems among children [6].

Food-based strategies greatly improve the nutritional quality of foods while posing little risk in many developing countries [7,8], making them effective, acceptable, and sustainable approaches to combating the devastating effects of malnutrition. One potential approach is the creation of affordable, nutrient-dense complementary/supplementary foods employing underutilized local cereal, legume, root, and tuber crops [7-9].

Complementary food refers to any solid foods or nutritious beverages, aside from breast milk, that are introduced to infants to supplement their diet when mother's milk alone is no longer sufficient. These foods are introduced to infants once they reach the age of six months, following a period of exclusive breastfeeding. Inadequate amounts and quality of complementary foods can result in elevated infection rates and other health complications in young children [6]. Research has indicated that more than 85% of the complementary foods given to infants fail to meet the nutrient density levels recommended by the World Health Organization (WHO), thereby contributing to malnutrition problems [10].

The aim of current research was to produce and investigate the potential nutrient-rich and appetizing complementary food products from readily available, wholesome, reasonably priced, and locally grown underutilized crops such as the *Moringa oleifera* mixed with cereals and other non-cereal starchy foods.

2. MATERIALS AND METHODS

Samples:Pearl millet and Orange fleshed sweet potato were obtained from Mawenzi market, in Morogoro, Moringa leaves were obtained from

Frida homestead, Morogoro. Dry dates were obtained from the Kilombero market, Arusha Tanzania.

Sample preparation: The processing steps for the preparation of Pearl millet, Orange fleshed sweet potato, Dates and Moringa leaf flour are shown in Fig. 1, and their respective flour sample are shown in Fig.2.

Preparation of Moringa leaf powder: A total of 3kg fresh Moringa leaves from the farm were sorted and the young and fresh leaves were selected. Damaged and diseased leaves were discarded. The leaves were washed with clean water and soaked in 1% NaCl for 5 minutes solution to inhibit microbial growth by increasing the osmotic pressure of the food medium. The excess water was drained and leaves were spread out on racks for 20 minutes before being shade dried at room temperature (28ºC) for 4 days. A high-speed multifunctional crusher Marada brand model 750A was used to ground the leaves to powder. A 500µm sieve was used to obtain a fine powder [11,12].

Preparation of Orange-Fleshed Sweet Potato Flour: A total of 6kg Sweet potatoes were washed, peeled, and chopped into (3mm thick) slices. The slices were oven dried at 50ºC overnight and later milled using a high-speed multifunctional crusher Marada model 750A. A 500µm sieve of the brand Alutec Food CAMPESATO was used to obtain a fine powder [13].

Germination and Preparation of pearl millet: A total of 10kg Pearl millet was sorted to remove extraneous matter and then washed to remove dust and mud. The sorted and cleaned millet was soaked in a 5 L bucket containing cold water for 10 hours at room temperature (28ºC). Water was drained from the millet grains and spread individually on wet muslin cloth where water was sprinkled at 6h break to stimulate the germination process. The millet grains germinated for 48 hours). The germinated millet was oven dried at 60°C for 10 h and then ground using a hammer mill from the brand Meadow Mills into flour. A 500µm sieve of the brand Alutec Food CAMPESATO was used to sieve germinated flour [14]. All the flour samples were kept in air-tight polyethylene bags and kept in a freezer at -10°C.

Preparation of Date Powder: A total of 1kg dried dates from the market were washed with clean water to remove dust. Inner seeds were also removed and the dates were kept in the oven for 12 hours at 60ºC. They were then left to dry for one hour. A high-speed multifunctional crusher model 750A was used to crush the dates so as to obtain a powder that was then sieved using a 500 µm [15].

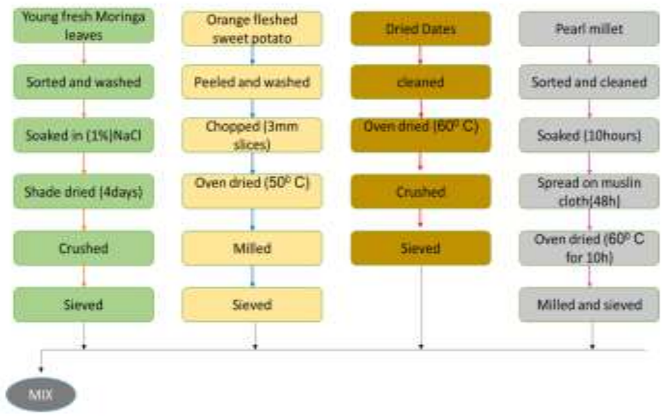


Fig. 1. Flowchart for the preparation of complementary food powder

Fig. 2. Flour and Powder for the complementary food ingridients

Formulation of potential complementary food: The linear regression method was used to combine the samples into different formulations to meet the FAO/WHO/UNICEF [16] requirement for micronutrients for young children and infants. Seven samples (including the control sample) were formulated as indicated in Table 1.

Proximate and mineral composition: The proximate composition of the product was determined according to official AOAC methods as shown below. Results were presented as means of duplicate determinations.

Crude fat: The total fat content was analyzed by using the official method 945.87 [17] for Soxhlet ether extraction. A dry sample weighing 5 g was placed into the extraction thimble and assembled in the Soxhlet apparatus. Reflux was conducted using 60 mL of petroleum ether in three distinct phases: a boiling phase of 15 minutes, a fat extraction phase of 30 minutes, and a petroleum ether recovery phase of 10 minutes. The recovered petroleum ether was evaporated, and the resulting fat was collected in pre-weighed cups using weight balanced (Reshy brand). To remove any remaining petroleum ether, the cups were dried in an oven at 105ºC for 30 minutes. After cooling in a desiccator for 20 minutes, the cups were weighed.

Table 1. Composition of complemented food from pearl millet, orange-fleshed sweet potato, date, and Moringa leaf (g/100 g)

Ingredients	Formulation Name	Ratios
Pearl Millet+ Moringa leaf powder+ Dates	PmMD1	90:2.5:7.5
	PmMD2	95:2.5:2.5
	PmMD3	88:03:09
Pearl Millet+ Moringa leaf powder+ Orange-fleshed sweet potato	PmMP1	95.5:2:2.5
	PmMP2	88:02:10
	PmMP3	95:2.5:2.5
Pearl Millet+ Dates + Orange- fleshed + sweet potato (Control sample)	PmDP	50:15:35

Key: Pm = Pearl Millet, M= Moringa Leaf, D= Dates, P= Orange fleshed sweet potatoes

Percentage fat was calculated by using the formula:

$$\% \, Crude\ fat = \frac{weight\ of\ crude\ fat\ (g)}{weight\ of\ dry\ sample\ (g)} \times 100$$

Ash content: The determination of ash content was conducted following the procedure outlined in AOAC [17], method 923.03. Initially, a dry sample weighing five grams was subjected to oven drying using an ESCO brand oven dryer at 105°C for duration of 24 hours. The weight of the crucible and the dried sample was accurately recorded. Subsequently, the dried samples contained within the crucibles were incinerated in a muffle furnace at a temperature of 550°C for a period of three hours, resulting in the formation of grey ash. The ash content was calculated as the variance between the weight of the sample before and after the incineration process.

Percentage ash was calculated from the relationship:

$$Ash\ (\%DM) = \frac{weight\ of\ ash\ (g)}{weight\ of\ dry\ sample\ (g)} \times 100$$

Crude protein: The determination of crude protein content in the samples was performed using the micro-Kjeldahl method 920.87 as specified in AOAC [17]. Initially, dried samples weighing 0.5 g were accurately weighed and transferred into digestion tubes. To each tube, 0.6 g of a catalyst mixture comprising 10 g of K_2SO_4 and 0.5 g of $CuSO_4$, along with 6 mL of concentrated H2SO4, were added. The samples were then digested using a Tecator digestion system 40 (Model 1016 digester, Sweden) for a duration of 3 hours, resulting in a clear greenish solution. After cooling, the digested solution was transferred to a distillation unit (Foss Tecator, Model 2200 Kjeltec auto distilling unit, Sweden). A total of 70 mL of distilled water was added to the digested solution, followed by 70 mL of 40% NaOH, and the mixture was steam distilled for 4 minutes. The distillate, measuring 50 mL, was collected in a conical Erlenmeyer flask containing 25 mL of 4% boric acid. The collected distillate was then titrated with 0.105 g/100 mL hydrochloric acid. A blank volume was also determined, and a value of 0.04 mL was obtained.

% Crude Proiten = (14.01 x (Title-Blank) x 6.25 x Concentraton of acid (n/mol) / weight of dry sample (g) x 10) x100

Where 6.25 is the protein-nitrogen conversion factor

Crude fiber: The determination of crude fiber content was conducted using the official method 920.86 outlined in AOAC [17]. The Ankom fiber analyzer (Model ANKOM 220, USA) was employed for this purpose. A sample weighing 1.0 g was subjected to digestion in the fiber analyzer using dilute sulfuric acid (0.125 M H_2SO_4) for a duration of 30 minutes. The resulting residues were then washed with hot water. Subsequently, the residues were digested using dilute alkali (0.125 M KOH) for 30 minutes and again washed with hot water. The digested residues were dried in an oven at 105°C for 5 hours, cooled, and weighed. The residues were further subjected to incineration in a muffle furnace at 550°C for 2 hours, followed by cooling and weighing. The difference in weight between the residues before and after incineration was considered as the total fiber content.

% Crude Fiber= ((weight of sample residues before incinaration-weight after) (g) / weight of dry sample (g)) x100

Carbohydrate: Carbohydrate was calculated as a percentage difference by the formula:

% Carbohydrate = 100 % – (% protein + % crude fiber + % crude fat + % Ash).

Energy: The energy content was calculated using the Atwater's conversion factors. Thus energy Values were obtained by multiplying % fat by factor 9, and % protein and % carbohydrate by factor 4 each [17].

Energy content = [(%Carbohydrate x 4) + (%Fat x 9) + (%protein x 4)]

Mineral Composition: The mineral composition analysis of the samples was conducted with a slight modification following the method described by Jachimowicz *et al.* [18]. Initially, the samples were sieved using a 1.18mm sieve. Then, 0.5g of each sample was accurately weighed and placed in vials. For digestion, 2ml of nitric acid (HNO_3) and water in a 1:1 ratio were added to each sample. Additionally, 5ml of hydrochloric acid (HCl) in a 1:4 ratio with distilled water was also included. The vials were covered with watch glasses.

Samples in the vials were heated in a hot block (Hot block 150 model: SC-154-240) at 95°C and boiled for 30 minutes until it reached 85°C. After this process, the vials were removed and allowed to cool down to room temperature. Subsequently, distilled water was added to each vial, making the total volume 50ml. The content of each vial was transferred to test tubes and then analyzed using the Inductively Coupled Plasma Optical Emission Spectrometry machine (ICP-OES-5900 Agilent) with the model number (Agilent 5900 SVDV ICP-OES), Serial number MY2215CP04, Software version 7.6.0.12121, and firmware version 5590). The results were displayed on the computer.

Vitamin A: The Vitamin A content in the samples was determined through the UV-VIS Spectrophotometry method by measuring β-carotene, its precursor in plants. To extract β-carotene, a mixture of 50 mL acetone-hexane with 0.1% BHT was added to 5g of the sample. After shaking for 10 minutes, the mixture was centrifuged and the supernatant was separated using a funnel. The resulting solution was saponified with 25 mL of 0.5M methanolic potassium hydroxide, followed by shaking and settling for 30 minutes, with subsequent washing using 100 mL portions of distilled water. The aqueous layer was continuously discarded, and the extract was dried by filtering over anhydrous sodium sulfate.

The filtrate was concentrated at 45°C using a rotary evaporator and then reconstituted in methanol to a final volume of 50 mL. Standard solutions with various concentrations were prepared using 95% UV β-carotene. A stock solution of 100 µg/mL was prepared by dissolving 0.01 g of β-carotene standard in 10 mL of hexane and then increased to 100 mL. The absorbance (A) of each concentration was measured at a wavelength of 450 nm using UV-VIS Spectrophotometry [12].

Data analysis: All data was analyzed by Statistical Package for Social Sciences (SPSS) version 25. One way analysis of variance (ANOVA) test was performed following a post-hoc test with significant differences being determined at 5% level ($p<0.05$). All results were expressed as mean ± SD of duplicate values.

3. RESULTS AND DISCUSSION

The chemical composition of complementary food blended with Moringa Leaf Powder (g/100 g dry weight) is summarized in Table 2. The composition was compared to the recommended daily intake for children aged 12-24 months by WHO (2005) and WHO/UNICEF (1998) (Table 3). The composition was also compared to the Tanzania standard for processed cereal based foods for infants and young children [19] indicated by the Tanzania Bureau of Standards (Table 3).

Fat: There was no significance difference ($p>0.05$) in crude fat among the samples. The values ranged from 0.66g/100g DM in PmMD2 to 1.38g/100g DM in PmMP3. Similar observations were made by Gebretsadikan *et al.* [20] where fat content of OFSP-Soybean-Moringa leaf porridge was not significantly altered. The results were due to inclusion of high levels of OFSP (60%-85%) and low levels of Soybean (10%-30%). A study by Bello *et al.* [21] reported that the fat content of the Pearl millet-OFSP-bean cookies was mainly from margarine that was added during preparations of the cookies. Pearl millet and OFSP have been reported to have low lipid content of 2.25% and 0.37% respectively [22,23]. This could also be the reason for low fat content observed in this study. A study by Haile *et al.* [24] on composite flour of OFSP and bulla *(Enset ventricosum)* flours had fat content of 0.2% to 0.8% which is also within the set standard although it was not sufficient for the daily requirements for adults who were the targeted group. Although the values obtained in the current study were much lower than those given in Table 3 (Tanzania standard, TZS180:2013)[19], they all met the set standard, and hence may be incorporated into infants food formulations complied.

Table 2. Proximate composition (g/100 g DM), energy (kcal/ 100 g) of Complementary food blended with Moringa Leaf Powder

Sample	Protein	Crude Fat	Fiber	Ash	Energy	Carbohydrates
PmDP	$8.34±0.01^{a}$	$1.10±0.07^{f}$	$3.33±0.00^{g}$	$2.13±0.19^{h}$	$352±0.76^{i}$	$77±0.04^{j}$
PmMD1	$10.09±0.05^{bc}$	$1.05±0.07^{f}$	$2.82±0.25^{g}$	$1.99±0.25^{h}$	$347±2.60^{i}$	$74±0.87^{k}$
PmMD2	$10.19±0.00^{cd}$	$0.66±0.49^{f}$	$3.23±0.32^{g}$	$2.00±0.30^{h}$	$346±0.57^{i}$	$74±0.96^{k}$
PmMD3	$11.07±0.28^{e}$	$0.98±0.01^{f}$	$3.01±0.02^{g}$	$2.23±0.25^{h}$	$347±1.42^{i}$	$73±0.60^{k}$
PmMP1	$9.92±0.06^{c}$	$1.29±0.04^{f}$	$2.85±0.34^{g}$	$2.03±0.09^{h}$	$348±2.22^{i}$	$74±0.51^{k}$
PmMP2	$9.72±0.03^{b}$	$1.25±0.03^{f}$	$3.10±0.31^{g}$	$2.04±0.08^{h}$	$348±0.28^{i}$	$74±0.10^{k}$
PmMP3	$10.58±0.00^{d}$	$1.38±0.06^{f}$	$2.69±0.58^{g}$	$1.99±0.21^{h}$	$350±0.39^{i}$	$74±0.24^{k}$

Means ± SD, values within the same column with different superscript letters are significantly different from each other ($p<0.05$)

Table 3. Recommended daily nutrient requirements for children aged 12-23 months

Nutrient	Requirement/day
Energy	900kcal
Protein	13g
Vitamin A	300µg
Iron	7mg
Zinc	3mg

Sources: WHO, (2005), WHO/UNICEF, (1998)

Ash: Ash refers to any inorganic material present in food or a residue that remains after heating and removing water. In current study, the ash content ranged between 1.99 to 2.13%. There was no significance difference ($p>0.05$) in ash content among all samples in this study. According to Gebretsadikan *et al.* [20] total ash content of OFSP-Moringa-Soybean porridge was positively influenced by OFSP and Moringa due to their high mineral content. A Study by Xu *et al.* (2020) support that potatoes have high mineral content. A study by Mohammed *et al.* (2016) on cookies reported that OFSP had higher contribution in mineral content of the cookies. Contrary to the present study, a study by Haile *et al.* [24] on porridge made from composite flour of OFSP and bulla reported a significant difference in ash among the samples. The study also indicated an increase in crude ash content as the amount of OFSP increased. Another study by Olaitan *et al.* [11] on quality evaluation of complementary food made from Pearl millet and Moringa leaf powder indicated an increase in the ash content as the amount of Moringa increased. All formulated samples under the current study were within the set levels as per TZS 180: 2013 indicated in Table 4.

Protein: Protein ranged between 8.34g/100g DM (52.1%) to 11.07g/100g DM (68.7%). There was a significant difference in protein content ($p<0.05$) among studied samples. This was from the samples with no Moringa to the sample that had the highest amount of Moringa of 3%. It was observed in this study that amount of increased protein content was directly proportional to Moringa Leaf Powder added This could be due to considerable amounts of protein that are found in Moringa. A study by Malla *et al.* 2021 reported 20% protein in the Moringa leaf. Other studies by Ntila [25] and Kayi [26] reported 20.47% and 30.3% of protein in dried Moringa leaf, respectively. Increased protein level in Moringa supplemented porridge could be due to significant amounts of protein found in Moringa leaves [27,28]. A study by Olaitan *et al.* [11] reported a significant difference in protein between the porridge samples upon addition of Moringa leaf powder. Increased protein content as the amount of Moringa was added in Moringa supplemented biscuits samples was reported by Hedhili *et al.* [29].

The protein content in this study is within the acceptable limit set by TZS 180:2013 but was below the limits set by WHO/UNICEF.

Table 4. Requirements for processed cereal-based foods for infants and young children

Characteristics	Requirements
Moisture content, % by mass, max.	Products for further processing 8.0
Total protein (quality at least 70% that of casein) by mass, min	14.0
Fat, % by mass, max.	8.5
Total carbohydrates, %by mass, min	60.0
Total ash, % by mass, max.	5.0
Ash insoluble in HCL, % by mass, max	0.05
Crude fiber (on dry basis), % by mass, max.	5
Vitamin A, IU/100g. min	500
Vitamin C mg/ 100g, min	25
Added Vitamin D, IU/100g.	25
Thiamine (as hydrochloride) mg/100g. min	300 to 800
Nicotine acid, mg/100g.min.	0.5
Calcium, mg/100g.max	1.0
Phosphorus mg/100g. min	25.0
Iron mg/100g, min	10

Source: TZS 180: 2013.

Crude Fiber: There was no significance difference (p>0.05) in crude fiber content among the samples in this study. The fiber content in the samples was contributed by Moringa and OFSP. A study by Gebretsadikan *et al.* [20] reported direct association of crude fiber with Moringa leaf powder and soybean. Moringa leaf powder is reported to have high fiber content than OFSP [27,30]. A study by Haile et al. [24] reported an increase in fiber content as OFSP was added to Bulla flour. A study by Olaitan et al. [11] on Pearl millet and Moringa leaf powder porridge reported a significant difference in fiber content. There was an increase in fiber content among the porridge samples as Moringa leaf powder was added. As per standards sets by TZS 180:2013 for crude fiber content all samples in this study complied with the specification.

Carbohydrates: Although the carbohydrate content ranged from 73 g/100g DM to 77 g/100g DM, there was a significant difference (p<0.05) in carbohydrates content between the control and all other samples except for sample PmMD2 among the samples in this study. The amount of carbohydrates from the product is contributed by both OFSP and pearl millet. Pearl millet contains 63-78% of carbohydrates [31]. The amount of carbohydrates increased significantly in the product as OFSP amounts were added, this is due to its high starch content [32]. A study by Gebretsadikan *et al.* [20] reported a limited impact on the changes of carbohydrates due to a narrow range of OFSP used in the mixture. Olaitan *et al.* [11] reported a decrease in the carbohydrate content in the porridge samples as the more Moringa leaf powder was added in the formulation. This is because Moringa has less carbohydrate content compared to pearl millet and hence reduced carbohydrates content in the sample. The Tanzania Bureau of Standards has set a minimum of 60% for carbohydrate content and all samples in this study have met the standard.

Energy: The energy content of the samples ranged between 346 kcal/100g DM and 352 kcal/100g DM There was no significant difference (p>0.05) in energy among the samples in this study. This could have been attributed by limited variation in the amount of ingredients used to develop the products. A study by Haile *et al.* [24] reported a significant difference in energy among the samples. The energy content was reported to increase as the amount of OFSP increased. A higher energy content of OFSP than that of bulla was reported to be responsible for the increased energy. All the samples in the study were below the energy set limits set by WHO/ UNICEF and Tanzania Bureau of Standards under TZS 180:2013.

Mineral Composition: The minerals and Vitamin A composition of Complementary food blended with Moringa Leaf Powder (g/100 g dry weight) is summarized in Table 5.

Iron: The Iron content of formulated products ranged from 4.5mg/100g to 6.3 mg/100g. There was no significant difference (p>0.05) in iron among the samples in this study. The amount of Iron increased as the amount of Moringa increased in the sample. Similar observations were made by Gebretsadikan *et al.* [20] in porridge samples where iron content increased as the amount of soybean and Moringa increased in the samples. Other studies by Abuye *et al.* [27] and Mellese *et al.* [28] had similar observations on the increase of iron content in the products as concentration of Moringa increased. Moringa leaves are a rich source of iron and other essential minerals [33]. A study by Govender & Siwela [34] reported an increase in iron content from bread fortified with 5% and 10% Moringa compared to the unfortified bread.

According to WHO/UNICEF the set standard for iron content in complementary food for a 12–24-month child is 7mg/100g. CODEX [35] has set a minimum of 4.8mg/100g while Tanzania Bureau of Standards under TZS 180:2013 has set a minimum of 10.87 mg/100g. All the samples in this study were below the limits set by WHO/UNICEF and TZS 180:2013. Six out of seven samples in the study reached the set limits made by CODEX [35].

Zinc: The zinc content ranged from 1.46mg/100g to 1.81mg/100g among the samples. There was no significance difference (p>0.05) in zinc among samples in this study. An increase in zinc content in the samples that had more amount of Moringa was observed. This implicates that addition of Moringa leaf powder boost the amount of zinc in food. Similar observations were made by Roni *et al.* [36] in the Moringa fortified cakes. According to CODEX [35] amount of zinc in the weaning food should have a minimum of 2.42mg/100g. On the other hand, WHO/ UNICEF have set a standard of 3mg/day of zinc for complementary foods for children of 12-23 months of age. All the samples in this study were below the requirements set by both CODEX and WHO/UNICEF.

Calcium: The calcium content of the porridge samples increased with the increase in the concentration of Moringa. There was a significant difference ($p<0.05$) in calcium content among the samples. The maximum calcium content of 240g/100g was recorded from the sample PmMD3 and the minimum calcium content of 183g/100g was recorded from the control sample PmDP. The increase in calcium levels in the samples is supported by the presence of calcium levels in Moringa leaves [37]. A study by Sengev *et al.* [38] reported a significant difference in calcium between bread samples fortified with Moringa and unfortified samples. According to FAO/WHO [39] the minimum calcium content of weaning foods should be 435mg/100g.

Vitamin A: The β- carotene content among the samples ranged from 308µg to 497 µg per 100g. There was a significant difference ($p< 0.05$) in β-carotene content among samples. The increase in β- carotene is due to addition of both Moringa leaf powder and Orange fleshed sweet potato. OFSP contains a significant amount of Pro vitamin A [40]. A study by Malla *et al.* [12] reported that Moringa leaf powder contains higher contents of β- carotene than Millet. The study also reported that β- carotene content improved in the Moringa fortified flour compared to the unfortified samples. It was furthermore reported in this study that β- carotene is one of the target nutrient that increased due to addition of Moringa. A study by Boateng *et al.* [41] supports that Moringa is a good fortificant to obtain enough amounts of Vitamin A. There were significant amounts of β- carotene in all the samples in this study due to addition of OFSP and Moringa, both of which have significant amounts of β- carotene. A study by Bello *et al.* (2022) reported that β- carotene content increased in cookies samples as OFSP increased. According to the Recommended Daily Intake of Vitamin A set by WHO/UNICEF for a 12–23-month-old, all the samples under this study reached the set limits.

Contribution of the nutrient's composition of the formulated porridge to the nutrient requirement of children aged 12-23 months.

Based on recommendations from UNICEF and WHO, children aged 12-23 months should be given three-quarter to a full cup (250mls) of complementary food per serving, with additional nutritious snacks offered 1-2 times per day as desired (WHO, 2009). However, according to FAO (2011), UNICEF (2010), and Brown (2003), children in this age group should ideally be given 3-4 servings a day due to their increased rate of growth and energy requirements as they continue to grow. If the porridge formulated in this study is provided to these children, it is assumed that children aged 12-23 months will consume a total of 1000mls per day (250mls per serving, 4 servings in a day).

The formulation labeled as "PmMP2," which was the most acceptable from the sensory evaluation panelists, could provide the following nutrients for children aged 12-23 months: 1,392 Kcal Energy, 38.8g crude protein, 1491 µg vitamin A, 21.6 mg Iron, and 5.6 mg Zinc. These nutrient levels exceed the recommended allowances for some nutrients targeted in this study. This indicates that the formulated porridge has the potential to provide beneficial nutritional contributions beyond the recommended amounts for children in this age group.

Another formulation that can be given to children aged 12-23 months is "PmMP3" which was the second most accepted formulation. If provided in 3 servings, a child will consume a total of 750mls per day. A child will obtain 1,050kcal Energy, 30g crude protein, 1119 µg vitamin A, 18.5mg Iron and 4.6mg Zinc from such diet. This formulation could also provide beneficial nutritional contributions beyond the recommended amounts for children in this age group. The Table 6 indicates amount that can be obtained in each nutrient and from every formulated mix when administered in 3 servings in a day.

All the samples in this study have shown to meet the stipulated standard set by WHO/UNICEF. Among all the samples the control sample PmDP provides the highest amount of energy. The sample PmMP2 provides the highest amount of Vitamin A. Iron, zinc, protein and calcium are obtained at a higher concentration in the porridge sample PmMD3. Although the sample PmMD3 has the highest amount of most nutrients it is among the least accepted sample in the sensorial aspect and therefore has the least chance to be taken.

Table 5. Mineral Composition (mg/100g DM), Vitamin A (µg/100g) of Complementary food blended with Moringa Leaf Powder

Samples	Iron	Zinc	Calcium	Vitamin A
PmDP	4.56 ± 0.22^{a}	1.51 ± 0.01^{b}	183 ± 2.12^{c}	441 ± 380^{ef}
PmMD1	5.77 ± 1.09^{a}	1.73 ± 0.04^{b}	237 ± 2.12^{d}	308 ± 535^{e}
PmMD2	5.85 ± 0.63^{a}	1.81 ± 0.16^{b}	236 ± 2.82^{d}	357 ± 368^{ef}
PmMD3	6.33 ± 0.66^{a}	1.81 ± 0.02^{b}	240 ± 0.70^{d}	434 ± 117^{ef}
PmMP1	5.7 ± 0.14^{a}	1.47 ± 0.67^{b}	202 ± 1.41^{e}	381 ± 680^{ef}
PmMP2	5.40 ± 0.57^{a}	1.46 ± 0.57^{b}	210 ± 0.70^{f}	497 ± 797^{f}
PmMP3	6.19 ± 0.14^{a}	1.54 ± 0.73^{b}	237 ± 2.12^{d}	373 ± 815^{ef}

Means ± SD, values within the same column with different superscript letters are significantly different from each other ($p<0.05$)

Table 6. Distribution summary of nutrients in each sample obtained from 3 servings per day

	Amount of nutrients obtained from 3 servings per day					
Sample	Energy (Kcal)	Iron (mg)	Zinc (mg)	Calcium(mg)	Protein (g)	Vitamin A (µg)
PmDP	1056	13.5	4.5	549	24	1323
PmMD1	1041	17.1	5.1	711	30	924
PmMD2	1038	17.4	5.4	708	30	1071
PmMD3	1041	18.9	5.4	720	33	1302
PmMP1	1044	17.1	4.2	606	30	1143
PmMP2	1044	16.2	4.2	630	29	1491
PmMP3	1050	18.5	4.6	711	30	1119

4. CONCLUSION AND RECOMMENDATION

The current study revealed that incorporating Moringa into the complementary food resulted in increased nutrient levels. For children aged 12-23 months to receive all the recommended daily nutrients, they would need to be provided with the amounts of meals as suggested by FAO/UNICEF. This research demonstrated that Moringa effectively improved the nutrient content of the complementary food. However, using more than 3% Moringa could further enhance the nutrient levels.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. UNICEF. Tracking Progress on Child and Maternal Nutrition. A survival and development priority: New York, NY 10017, USA; 2009.
2. Muhimbula HS, Issa-Zacharia A. Persistent child malnutrition in Tanzania: Risks associated with traditional complementary foods (A review). African Journal of Food Science. 2010;4(11):679 – 692.
3. Mosha T, Laswai S, Tetens I. Nutritional composition and micronutrient status of home made and commercial weaning foods consumed in Tanzania. Plant Foods Human Nutrition. 2000;55(3):185-205.
4. Haidar J, Muroki NM, Omwega AM, Ayana G. Malnutrition and deficiency in breast feeding women in urban slum communities from Addis Ababa, Ethiopia. East African Medical Journal. 2003;80(4):191-194.
5. Kikafunda JK, Abenakyo L, Lukwago FB. Nutritional and sensory properties of high energy/nutrient dense composite flour porridges from germinated maize and roasted beans for child-weaning in developing countries: A case for Uganda. Ecology of Food and Nutrition. 2006;45:279-294
6. FAO, IFAD and WFP. The State of Food Insecurity in the World. FAO, Rome. 2015;62.
7. Omar D, Michael H. The food fortification formulator: technical determination of fortification levels and standards for mass fortification", Academy for Educational Development and United States Agency for International Development (USAID); 2008.
8. WHO/FAO, Guidelines on Food Fortification with Micronutrients, Geneva. 2006;3-328.
9. Forsido SF, Rupasinghe HPV, Astatkie T. Antioxidant capacity, total phenolics and nutritional content in selected Ethiopian staple food ingredients.

International Journal of Food Sciences and Nutrition. 2013;64(8):915-920.
10. Tenagashaw MW, Kinyuru JN, Kenji GM, Melaku ET, Susanne HK. Nutrient density of complementary foods formulated from a blend of Teff, Soybean and Orange-fleshed Sweet Potato. International Journal of Food Science and Nutrition Engineering. 2017;7(4):61-69.
11. Olaitan NI, Eke MO, Uja EM, Oja EA. Quality evaluation of complementary food formulated from Moringa Oleifera leaf powder and pearl millet (*Pennisetum glaucum*) flour. International Journal of Enginering and Science. 2014;3(11):59-63.
12. Malla JK, Ochola S, Ogada I, Munyaka A. Nutritional Value and Sensory Acceptability of M. oleifera Fortified Finger Millet Porridge for Children with Cerebral Palsy in Nairobi County, Kenya;2021.
13. Falade KO, Solademi OJ. Modelling of air drying of fresh and blanched sweet potato slices. International Journal of Food Science & Technology. 2010;45(2):278-288.
14. Nefale FE, Mashau ME. Effect of germination period on the physicochemical, functional and sensory properties of finger millet flour and porridge. Asian Journal of Applied Sciences. 2018;6(5).
15. Hasan MU, Malik AU, Ali S, Imtiaz A, Munir A, Amjad W, Anwar R. Modern drying techniques in fruits and vegetables to overcome postharvest losses: A review. Journal of Food Processing and Preservation. 2019;43(12):e14280.
16. FAO. Guidelines for development of supplementary foods for older infants and young children. Report of the 14th Session of the Codex Committee on Foods for Special Dietary Uses; 1985.
17. AOAC. Official Methods of Analysis.16th Edition. Association of Official Analytical Chemists, Washington, D. C, USA. 1999;54.
18. Jachimowicz K, Winiarska-Mieczan A, Baranowska-Wójcik E, Bąkowski M. Pasta as a Source of Minerals in the Diets of Poles; Effect of Culinary Processing of Pasta on the Content of Minerals. Foods. 2021;10(9):2131.
19. TZS 180. Tanzania Bureau of Standards: Specification for processed cereal-based foods for infants and young children-Specification, Tanzania Standards. 2013;20.
20. Gebretsadikan TM, Bultosa G, Forsido SF, Astatkie T. Nutritional quality and acceptability of sweet potato–soybean–moringa composite porridge. Nutrition & Food Science. 2015;45(6):845-858.
21. Bello FA, Folademi MA, Iwok LJ. Development of pearl millet flour-based cookies supplemented with mung bean and orange fleshed sweet potato flours. The Annals of the University Dunarea de Jos of Galati. Fascicle VI-Food Technology. 2022;46(1):155-168.
22. Adebiyi JA, Obadina AO, Adebo OA, Kayitesi E. Comparison of nutritional quality and sensory acceptability of biscuits obtained from native, fermented, and malted pearl millet (Pennisetum glaucum) flour. Food Chemistry. 2017;232:210-217.
23. Kolawole FL, Balogun MA, Oyeyinka SA, Adejumo RO, Sanni-Olayiwola HO. Effect of processing methods on the chemical composition and bio-accessibility of beta-carotene in orange-fleshed sweet potato. Journal of Food Processing & Preservation. 2020;e14538.
24. Haile A, Geribo M, Kinfe E. Evaluation of porridge made from composite flour of orange-fleshed sweet potato and Enset (Bulla) flours. Agriculture and Food Sciences Research. 2016;3(1):37-44.
25. Ntila SL. The potential of Moringa oleifera (Lam.) leaves for use in complementary foods to combat child food and nutrition insecurity among South African rural and peri-urban communities [PhD Thesis].University of KwaZulu-Natal; 2017.
26. Kayi KK. A study on Moringa oleifera leaves as a supplement to West African weaning foods. Hamburg University of Applied Sciences; 2013.
27. Abuye C, Urga K, Knapp H, Selmar K, Omwega AM, Imungi JK, Winterhalter P. A compositional study of Moringa stenopetala leaves. East African Medical Journal. 2003;80(5):247-250.
28. Melesse A, Bulang M, Kluth H. Evaluating the nutritive values and in vitro degradability characteristics of leaves, seeds and seedpods from Moringa stenopetala.
Journal of the Science of Food and Agriculture. 2009;89(2):281-287.
29. Hedhili A, Lubbers S, Bou-Maroun E, Griffon F, Akinyemi BE, Husson F, Valentin D. Moringa Oleifera supplemented biscuits: Nutritional values and consumer

segmentation. South African Journal of Botany. 2021;138:406-414.

30. Senanayake SA, Ranaweera KKDS, Gunaratne A, Bamunuarachchi A. Comparative analysis of nutritional quality of five different cultivars of sweet potatoes (*Ipomea batatas* (L) Lam) in Sri Lanka", Food Science and Nutrition. 2013;1(4): 284-291
31. Taylor JRN, Kruger J. Millets. Encyclopedia of Food and Health (pp. 748–757) Oxford: Academic Press; 2016.
32. Faber M, Laurie S, Ball A, Andrade M. A crop-based approach to address vitamin a deficiency in Southern Africa – a regional manual for SADC. ARC-Roodeplaat, Pretoria. 2010;65-84.
33. Gandji K, Chadare FJ, Idohou R, Salako VK, Assogbadjo AE, Kakaï RG. Status and utilisation of Moringa oleifera Lam: A review. African Crop Science Journal. 2018;26(1):137-156.
34. Govender L, Siwela M. The effect of moringa oleifera leaf powder on the physical quality, nutritional composition and consumer acceptability of white and brown breads. Foods. 2020;9(12):1–17.
35. CODEX. Codex Alimentarius Commission: CODEX STAN 074-1981, REV.1-2006-Standards for processed cereal-based foods for infants and young children. 2006;27.
36. Roni RA, Sani MNH, Munira S, Wazed MA, Siddiquee S. Nutritional Composition and Sensory Evaluation of Cake Fortified with Moringa oleifera Leaf Powder and Ripe Banana Flour. Applied Sciences. 2021;11 (18):8474.
37. Kasolo JN, Bimenya GS, Ojok L, Ochieng J, Ogwal-Okeng JW. Phytochemicals and uses of Moringa oleifera leaves in Ugandan rural communities. Journal of Medicinal Plants Research. 2010;4(9): 753–757.
38. Sengev AI, Abu JO, Gernah DI. Effect of Moringa oleifera leaf powder supplementation on some quality characteristics of wheat bread. Food and nutrition sciences. 2013;4(3):270.
39. Joint FAO, WHO Expert Committee on Nutrition, & World Health Organization. Joint FAO/WHO Expert Committee on Nutrition: eighth report, food fortification, protein-calorie malnutrition, Geneva, Switzerland, 9-18 November 1970. World Health Organization; 1971.
40. Bechoff A. Investigating carotenoid loss after drying and storage of orange fleshed sweetpotato. PhD thesis, Greenwich University. 2010;75-102.
41. Boateng L, Nortey E, Ohemeng AN, Asante M, Steiner-Asiedu M. Sensory attributes and acceptability of complementary foods fortified with Moringa oleifera leaf powder. Nutri Food Sci. 2019;49(3):393-406.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/106620

CHAPTER FOUR

4.0 GENERAL DISCUSSION

4.1 Nutritional Quality of the Porridge

The purpose of this study was to evaluate the nutritional value of a porridge made from dates, pearl millet, orange-fleshed sweet potatoes, and Moringa leaf powder. In order to combat malnutrition, this was done to determine whether the porridge met the nutritional requirements for young children (1-2 years old). Analyses of proximate, minerals (Iron, Zinc, Calcium), and vitamin A were done. The research revealed that the fat contents were comparable among samples. These outcomes have been related to the low lipid content of orange-fleshed sweet potatoes and pearl millet (Kolawole *et al.,* 2020). A similar trend was demonstrated by the ash content which rose with an increase in the OFSP levels. There was no evidence of ash content change between the samples. A Study by Olaitan *et al*. (2014) made comparable findings. It was discovered that the samples varied in their protein concentration. The findings suggested that Moringa played a role in the variance of the outcome. As the amount of Moringa in the samples rose, the protein content similarly rose.

The addition of OFSP and Moringa to the samples contributed to their fiber content. Since the quantities of OFSP and Moringa were not significantly different, the findings suggested that the fiber content across the samples was similar. Haile et al. (2016) found that fiber content increased with higher concentrations of OFSP in the samples. Notably, the variation in carbohydrates was mainly influenced by pearl millet and OFSP, aligning with similar findings by Olaitan *et al.* (2014).

The samples exhibited discrepancies in protein concentration, while there was no discernible difference in energy content, attributed to slight variations in component quantities used in porridge preparation. During mineral analysis, similarities were observed in iron and zinc contents across the samples, with concentrations increasing alongside Moringa amounts, consistent with findings by Gebretsadikan *et al.* (2015). Conversely, calcium content varied significantly among samples, likely due to the presence of Moringa, supported by findings from Sengev *et al.* (2013), indicating higher Moringa quantities correlated with increased calcium content. Additionally, due to its high Vitamin A content, Moringa significantly contributed to variations in Vitamin A levels across the samples, as demonstrated by Bechoff (2010).

By including Moringa in the samples, young children can potentially fulfill their recommended daily nutrient intake if they consume the recommended frequency of meals (3–4 per day) as advised by WHO/UNICEF.

4.2 Functional Quality of the Porridge

The functional characteristics of bulk density, water absorption capacity, and viscosity were applied to the samples. It is demonstrated that the samples' bulk density, which gauges the flour's weight, varies. It was discovered that when Moringa, dates, and OFSP amounts grew larger, so did bulk density. According to reports, adding more components to pearl millet flour enhanced its bulk density. Water absorption Capacity, which measures how much space starch polymers occupy after swelling in excess water, was shown to be consistent across samples. According to Haile *et al*. (2016), the protein content of Moringa was the reason for the increased ability to absorb water. The varying amount of OFSP that contains a high amount of starch caused variation in the scores for viscosity, giving higher results to the samples that have more OFSP. This is consistent with a research by Haile *et al*. (2016).

4.3 Sensory Quality of the Porridge

The consumer test findings unveiled variations in color among the samples, primarily attributed to the positive impact of OFSP on porridge acceptance contrasted with Moringa's green hue, which detrimentally affected product appeal. Interestingly, both ingredients wielded equal influence over flavor, aroma, and overall acceptability. Recommended samples tended to feature higher OFSP content and lesser Moringa. These results are consistent with prior studies by Boateng et al. (2019) and Gebretsadikan et al. (2015). Notably, the PCA biplot demonstrated a close correlation between aroma and thickness, unlike attributes such as grittiness, sweetness, and color, which exhibited no discernible associations. Quantitative descriptive analysis further revealed disparities in sweetness among all samples, while attributes like color, aroma, grittiness, and thickness were observed to be consistent across the board.

REFERENCES

Boateng, L., Nortey, E., Ohemeng, A. N., Asante, M., & Steiner-Asiedu, M. (2019). Sensory attributes and acceptability of complementary foods fortified with Moringa oleifera leaf powder. *Nutri Food Sci., 49*(3), 393-406.

Gebretsadikan, T. M., Bultosa, G., Forsido, S. F., & Astatkie, T. (2015). Nutritional quality and acceptability of sweet potato–soybean–moringa composite porridge. *Nutrition & Food Science*, *45*(6), 845-858.

Haile, A., Geribo, M., & Kinfe, E. (2016). Evaluation of porridge made from composite flour of orange-fleshed sweet potato and Enset (Bulla) flours. *Agriculture and Food Sciences Research*, *3*(1), 37-44.

Kolawole, F.L., Balogun, M.A., Oyeyinka, S.A., Adejumo, R.O., Sanni-Olayiwola, H.O. (2020). Effect of processing methods on the chemical composition and bio-accessibility of beta-carotene in orange-fleshed sweet potato. *Journal of Food Processing & Preservation*, *44*(7), e14538.

Olaitan, N. I., Eke, M. O., Uja, E. M., & Oja, E. A. (2014). Quality evaluation of complementary food formulated from Moringa Oleifera leaf powder and pearl millet (Pennisetum Glaucum) flour. *International Journal of Enginering and Science*, *3*(11), 59-63.

CHAPTER FIVE

5.0 GENERAL CONCLUSION AND RECOMMENDATION

5.1 Conclusion

According to the current study, adding Moringa to the supplemental food raised the amount of nutrients present. Children between the ages of 12 and 23 months must be fed the amounts of meals recommended by FAO/UNICEF in order for them to receive all of the essential daily nutrients. This study showed that adding Moringa to the supplemental food significantly increased its nutritious content. Nevertheless, adding more than 3% Moringa could raise the nutritious content even further. Other meals can be added to Moringa to cover up its unpleasant leafy odor, bitter flavor, and deep green appearance. This allows young children to enjoy the food without experiencing any sensory problems and still reap the nutritious benefits of Moringa.

This study demonstrates how functional characteristics affect a product's desirability. In order to increase the product's acceptability, it is crucial to make sure that the functional factors are taken into account and properly worked on. Specific sensory characteristics like color, flavor, and scent enhanced the product's overall acceptance. The functional factors are important in identifying qualities related to storage, transportation, and distribution in addition to indicating sensory appeal. When Moringa leaf powder was added to the samples, there was a noticeable shift in taste and color. The product's acceptance in terms of color and taste has been impacted by its deep green color and bitter taste. The acceptance of the samples was enhanced by the addition of dates and orange-fleshed sweet potatoes. Additionally, it has demonstrated excellent benefits in enhancing the porridge samples' functioning properties. Its excellent nutritional profile, as well as its sensory and functional attributes, calls for frequent application in the creation of new food products. Given Moringa oleifera excellent nutritional profile, it ought to be included in meals that go well with it. Foods should only contain extremely little amounts of Moringa, preferably combined with other ingredients that can help to disguise the plant's bitter flavor and color.

5.2 Recommendations

Ideal Moringa Inclusion: To prevent an overabundance of nutrients, it is best to make sure that the amount of Moringa in supplemental foods for young children does not go above 3%. This degree of inclusion achieves a compromise between maintaining sensory acceptability and improving nutritional value.

Various Complementary products: It is advised to blend Moringa with other products to lessen its slightly disagreeable leafy odor, bitter taste, and deep green look. This will enhance the food's sensory qualities while also providing a diversity of flavors and textures, which will appeal to young children more.

Advised according to Age: According to the study, the most favored sample was PmMP2 (88% pearl millet, 2% Moringa leaf powder, and 10% orange-fleshed sweet potato). Toddlers who are one to three years old are advised to use it. This emphasizes how crucial it is to design food items with particular age groups in mind to suit the dietary and sensory requirements of kids at various stages of development.

Functional Quality Considerations: It is crucial to consider functional aspects including distribution, transportation, and storage while creating food products. These elements have a big impact on the products' overall acceptance and quality. Considerations such as color, flavor, and aroma can improve the product's consumer acceptability.

Well-Balanced Nutritional Profile: Although Moringa has a very good nutritional profile, it is important to use it sparingly in meals. To hide its bitter taste and bright green color while maintaining its nutritious value, the study advises using it sparingly and combining it with other substances.

Future Research: To improve the nutritional value and sensory appeal of Moringa, further methods of incorporating it into meals should be investigated. It would also be beneficial to look at how diets enhanced with Moringa affect young children's long-term nutritional status and overall health.

APPENDICES

Appendix 1: Consumer acceptability sensory evaluation questionnaire

Name of panelist…………………………………….

Age……………………………**Sex**……..

Date………………

You are provided with different porridge samples which you have to assess. Carefully start from left to right, observe the sample and assess them for; (i) Color (ii) Aroma (iii) Taste (iv) overall acceptability. Please indicate the number which best describes your feeling using appropriate number (1-7) in the column by using hedonic scale provided below. Please take a sip of water and rinse your mouth before and after testing any sample.

Hedonic scale

KEY

1- Dislike very much
2- Dislike moderately
3- Dislike slightly
4- Neither like nor dislike
5- Like slightly
6- Like moderately
7- Like very much

Indicate your degree of liking here

	Samples						
ATTRIBUTE	370	935	475	740	850	210	136
Color							
Aroma							
Taste							
Overall acceptance							

Other recommendations

…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………….

Thank you.

Appendix 2: Quantitative Descriptive Analysis sensory evaluation questionnaire

Panelist name……………………………………………..

Sex……………..………………………. Age…………………………

Time……….

You are provided with seven coded samples of porridge, please kindly evaluate the samples and indicate the intensity of each attribute as provided in the table below using the line scale provided.

Color

Low 1 2 3 4 5

high

Aroma

Low 1 2 3 4 5

high

Sweetness

Not sweet 1 2 3 4 5

very sweet

Thickness

Not viscous

1 2 3 4 5 very viscous

Grittiness

Low 1 2 3 4 5 high

Indicate your degree of intensity here

	Sample code						
Attribute	370	935	475	740	850	210	136
Color							
Aroma							
Sweetness							
Thickness							
Grittiness							

Other recommendations

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

Thank you

Appendix 3: Letter of Clearance from SUA

CLEARANCE PERMIT FOR CONDUCTING RESEARCH IN TANZANIA

UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY.

SOKOINE UNIVERSITY OF AGRICULTURE
OFFICE OF THE VICE-CHANCELLOR

P.O Box 3000, CHUO KIKUU, MOROGORO, TANZANIA.
Phone: +255 (023) 2640006/7/8/9, Direct Line: +255 (023) 2640015,
E-mail: vc@sua.ac.tz, Website: https://www.sua.ac.tz

Please refer to:
Our Ref: SUA/ADM/R.1/8/997

Date: 18th January, 2023

Permanent Secretary,
President's Office,
Regional Administration and Local Government,
P.O. Box 1923, Mji wa Serikali,
41185 DODOMA.
Email: ps@tamisemi.go.tz

RE: UNIVERSITY STAFF, STUDENTS AND RESEARCHERS CLEARANCE

The Sokoine University of Agriculture was established by University Act No. 7 of 2005 and SUA Charter, 2007 which became operational on 1st January 2007 repealing Act No. 6 of 1984. One of the mission objectives of the University is to generate and apply knowledge through research. For this reason the staff and researchers undertake research activities from time to time.

2. To facilitate the research function, the Vice Chancellor of the Sokoine University of Agriculture (SUA) is empowered to issue research clearance to staff, students, research associate and researchers of SUA on behalf of the Tanzania Commission for Science and Technology.

3. The purpose of this letter is to introduce to you **Ms. Salha Y. selemani** a bonafide **MSc. (Food Quality and Safety Assurance)** student with Registration number **MFQ/D/2021/0015** of SUA. By this letter **Ms. Salha Y. selemani** has been granted clearance to conduct research in the country. The title of the research in question is ***"ENRICHMENT OF PEARL MILLET AND ORANGE FLESHED SWEET POTATO PORRIDGE WITH MORINGA LEAF POWDER FOR TODDLERS".***

4. The period for which this permission has been granted is from **February, 2023** to **July, 2023**. The research will be conducted in **SUA, Morogoro in Morogoro Region and Nyamagana District in Mwanza Region.**

5. Should some of these areas/institutions/offices be restricted, you are requested to kindly advice the researcher(s) on alternative areas/institutions/ offices which could be visited. In case you may require further information on the researcher please contact me.

6. We thank you in advance for your cooperation and facilitation of this research activity.

Yours sincerely,

Prof. Juma S. Kabote
FOR: VICE-CHANCELLOR

c.c. Director, DPRTC, SUA. - To note in file.
c.c. Student – **Ms. Salha Y. selemani**

Appendix 4: Turnitin Originality report

DEVELOPMENT AND ACCEPTABILITY OF MORINGA FORTIFIED PORRIDGE FOR CHILDREN AGED 1-2 YEARS

ORIGINALITY REPORT

26%	21%	16%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	suaire.suanet.ac.tz Internet Source	3%
2	pdfs.semanticscholar.org Internet Source	3%
3	www.suaire.sua.ac.tz Internet Source	2%
4	stud.epsilon.slu.se Internet Source	2%
5	Emmanuel C. Mrimi, Marta S. Palmeirim, Elihaika G. Minja, Kurt Z. Long, Jennifer Keiser. "Malnutrition, anemia, micronutrient deficiency and parasitic infections among schoolchildren in rural Tanzania", PLOS Neglected Tropical Diseases, 2022 Publication	2%
6	www.researchgate.net Internet Source	1%

Kuhusu Tasnifu Hii

Utafiti huu unaonyesha kuwa kutokuwa na lishe kamili ni tatizo kubwa la afya nchini Tanzania, hasa miongoni mwa watoto wadogo. Upungufu wa chakula na mienendo isiyo sahihi ya kutoa vyakula vya kuongeza vinachangia tatizo hili. Kuongeza Mlonge kwenye vyakula vya kuongeza inaonekana kuwa njia yenye matumaini ya kuboresha hali ya lishe ya watoto. Utafiti unaonyesha kuwa vyakula vyenye Mlonge vinaweza kuongeza maudhui ya virutubisho, lakini ni muhimu kuzingatia kiwango sahihi cha kuongeza ili kuepuka kupita kiasi. Aidha, ubora wa vyakula hivyo na kukubalika kwa watumiaji ni mambo muhimu katika kufanikisha lengo la kuboresha lishe ya watoto. Hivyo, kupitia kuboresha vyakula vya watoto vyenye Mlonge na viungo vyenye afya, inawezekana kuchangia kwa kiasi kikubwa katika kupambana na tatizo la kutokuwa na lishe kamili miongoni mwa watoto nchini Tanzania. Hii inaweza kuwa njia ya kuleta mabadiliko chanya katika afya na maendeleo ya kizazi kijacho.