Sokoine University of Agriculture

MSc Dissertation

Enhancing The Nutritional Content of Noodles Produced by Small Scale Processors in Tanzania

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ENHANCING THE NUTRITIONAL CONTENT OF NOODLES PRODUCED BY SMALL SCALE PROCESSORS IN TANZANIA

The Dissertation Is Submitted to Sokoine University of Agriculture in Partial Fulfilment of the Requirements for the Master Degree in Food Quality and Safety Assurance

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EXTENDED ABSTRACT

Background: Noodles have become increasingly popular in the country due to their convenience and affordability in terms of price. This trend can be attributed to urbanization and changing lifestyles. However, the widespread consumption of noodles has raised concerns about their nutritional deficiencies. Many noodle products lack essential nutrients such as vitamins, minerals and protein, crucial for maintaining a balanced and healthy diet. Excessive reliance on noodles as a staple food can lead to nutritional imbalances and deficiencies, contributing to health problems among the population. As such, promoting a diverse and well-balanced diet is important to address these nutritional shortcomings in Tanzania. This research aimed to address this issue by enhancing noodle's nutritional composition and sensory qualities by incorporating *Moringa oleifera* leaf powder and sardine powder, targeting small-scale processors.

Methods: an experimental research design was employed to investigate the nutritional, textural, cooking quality and sensory acceptability impact of adding *Moringa oleifera* leaf powder and sardine powder to wheat-based noodle formulations. Six formulations were prepared, altering the ratios of wheat, *Moringa oleifera* leaf powder, and sardine powder. For the Moringa-fortified noodles, ratios included 99.6% wheat and 0.4% moringa (WM1), 99.2% wheat and 0.8% moringa (WM2), and 99% wheat and 1% moringa (WM3). For sardine-fortified noodles, formulations comprised 95% wheat and 5% sardine (WS1), 90% wheat and 10% sardine (WS2), 85% wheat and 15% sardine (WS3), with a 100% wheat control (WC). The nutritional parameters assessed included crude protein, fibre, fat, ash, carbohydrate, energy content, and mineral composition, including calcium, magnesium, iron, and zinc. For the proximate and mineral composition, data were analyzed using SPSS (Statistical Package for the Social Sciences Version 26.0, SPSS Inc., Chicago, IL, USA) software whereby one-way

Anova and post- hoc test (HSD) were performed to check if there is a significant difference in nutritional composition at level of significance $p<0.05$ and all the data were reported using mean values of determinations ± standard deviation. Similarly, Textural properties, including hardness, cohesiveness, springiness, and adhesiveness, were measured. Additionally, cooking quality attributes such as cooking loss, volume increase, and water absorption were assessed. Sensory evaluations were conducted at Morogoro Secondary School, where 60 panellists aged 14-19 were to gauge consumer acceptability concerning colour, aroma, texture, taste, and overall acceptability. The quantitative descriptive analysis was also performed at the Sokoine University of Agriculture, Department of Food Science and Agro-processing, with 10 trained panellists to identify specific changes in attributes like colour, aroma, saltiness, and hardness due to the inclusion of moringa and sardine powders. 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 Tukey'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 as well as partial least square regression (PLSR) was performed by unscrambler X software version 10.4 to check the relationship between quantitative descriptive data and consumer data.

Results: The results indicated significant variations in the nutritional composition of the different noodle formulations compared to the control sample. Incorporating *Moringa oleifera* leaf powder and sardine powder led to notable increases in crude protein and mineral content, such as iron, calcium, magnesium, and zinc. The nutritional profile of the noodles was positively altered, suggesting that the incorporation of moringa leaf and sardine powders enhances the nutritional value of the final product. In dry matter basis, crude protein ranged from 11.76-21.40 g/100g, crude fibre 0.00-0.02 g/100g, crude fat 1.89-2.94 g/100g, ash 1.38-2.26 g/100g, carbohydrate 62.31-74.29 g/100g, and energy 358.50-364.53 kcal/100g. The mineral content showed that iron ranged from 32.55 to 65.50 mg/100g, calcium from 7.39 to 66.61 g/100g, magnesium from 28.86 to 87.35 mg/100g, and zinc from 2.21 to 39.25 mg/100g. Therefore, the incorporation of moringa and sardine powders exhibited the potential to enhance the nutritional value of noodles.

Moreover, incorporating moringa leaf and sardine powders decreased hardness and cohesiveness, making the noodles softer and less cohesive as the powders' concentrations increased. Furthermore, cooking loss, volume increase and water absorption were assessed, revealing that higher concentrations of these powders led to increased cooking loss and reduced volume and water absorption, affecting the noodles' texture and water-holding capacity. Sensory evaluations were also performed, demonstrating that higher concentrations of moringa leaf and sardine powders led to changes in the sensory attributes of the noodles, with lower concentrations generally receiving higher acceptability scores. Additionally, the quantitative descriptive analysis highlighted that adding these powders altered specific characteristics of the noodles, such as colour, aroma, saltiness, and hardness, with more significant alterations at higher powder concentrations.

Conclusion: These combined findings suggest that incorporating *Moringa oleifera* leaf powder and sardine powder into noodle formulations can be a viable approach to improve their nutritional content. However, carefully considering the sensory impact and the desired balance between nutrition and sensory attributes is crucial. Small-scale processors in Tanzania can use these insights to develop noodles that are more nutritious and appealing to consumers, contributing to improved food choices and potentially addressing nutritional challenges. In summary, this research offers

valuable insights into a viable approach to improve the nutritional quality of commonly consumed foods, benefiting both the food industry and consumers in Tanzania.

IKISIRI KUU

Historia: Tambi zimekuwa maarufu nchini kutokana na urahisi na bei nafuu. Huu mwenendo wa upishi unaweza kutokana na mchakato wa mji na mabadiliko ya mtindo wa maisha. Hata hivyo, matumizi makubwa ya tambi yameleta wasiwasi kuhusu upungufu wa virutubishi. Bidhaa nyingi za tambi hazina virutubishi muhimu kama vile vitamini, madini, na protini, ambavyo ni muhimu kwa lishe bora na afya. Kutegemea sana tambi kama chakula cha kawaida kunaweza kusababisha upungufu wa lishe na kuchangia matatizo ya afya kwa idadi ya watu. Hivyo, ni muhimu kuhamasisha lishe mbalimbali na inayowiana ili kushughulikia mapungufu haya ya lishe nchini Tanzania. Utafiti huu unalenga kutatua suala hili kwa kuboresha muundo wa lishe na sifa za hisia za tambi kwa kuingiza unga wa majani ya Mlonge na unga wa dagaa, ukilenga wazalishaji wadogo wa tambi.

Njia: Utafiti wa majaribio ulitumika kuchunguza athari za kiwango cha lishe, muundo wa mlo, na ubora wa upishi wa tambi zinazotengenezwa kwa unga wa ngano kwa kuongeza unga wa majani ya Mlonge na unga wa dagaa. Jumla ya mchanganyiko wa tambi sita ulitayarishwa, ukiwa na mabadiliko ya uwiano kati ya unga wa ngano, unga wa majani ya Mlonge, na unga wa dagaa. Kwa tambi zilizoboreshwa na Mlonge, uwiano ulijumuisha 99.6% ngano na 0.4% Mlonge (WM1), 99.2% ngano na 0.8% Mlonge (WM2), na 99% ngano na 1% Mlonge (WM3). Kwa tambi zilizoboreshwa na dagaa, mchanganyiko ulihusisha 95% ngano na 5% dagaa (WS1), 90% ngano na 10% dagaa (WS2), 85% ngano na 15% dagaa (WS3), na kudhibiti bila kuongeza kitu (WC). Vigezo vya lishe vilivyohusishwa ni pamoja na protini ghafi, nyuzi ghafi, mafuta ghafi, majivu, wanga, na kiwango cha nishati, pamoja na muundo wa madini, ambao ni pamoja na kalsiamu, magnesiamu, chuma, na zinki. Kwa muundo wa protini na madini, data ilichambuliwa kwa kutumia programu ya SPSS (Statistical Package for the Social Sciences, Toleo la 26.0, SPSS Inc., Chicago, IL, USA) ambapo uchambuzi wa Anova wa njia moja na mtihani wa post-hoc (HSD) ulifanywa kuchunguza ikiwa kuna tofauti kubwa katika muundo wa lishe kwenye kiwango cha umuhimu $p <0.05$, na data zote ziliwasilishwa kwa kutumia wastani wa vipimo ± kipimo cha kawaida. Vivyo hivyo, mali za kiunzi, ikiwa ni pamoja na ugumu, urahisi wa kushikana, upya, na utambaa, zilipimwa. Aidha, vigezo vya ubora wa upishi kama upotezaji wa kupika, ongezeko la kiasi, na unyonyaji wa maji vilichunguzwa. Uchunguzi wa hisia ulifanywa katika shule ya sekondari ya Morogoro ambapo wapimaji 60 wenye umri kati ya miaka 14-19 walitumika kugundua uwezekano wa kukubalika kwa watumiaji kuhusiana na rangi, harufu, muundo, ladha, na kukubalika kwa jumla. Uchambuzi wa maelezo kwa kiasi kikubwa pia ulifanywa katika Chuo Kikuu cha Sokoine cha Kilimo, Idara ya Sayansi ya Chakula na Uongezaji wa Mazao na wapimaji 10 waliofundishwa kutambua mabadiliko maalum katika sifa kama rangi, harufu, chumvi, na ugumu kutokana na kuongeza unga wa Mlonge na unga wa dagaa. Uchambuzi wa data za takwimu ulifanywa kwa kutumia programu ya SPSS (Statistical Package for the Social Sciences, Toleo la 26.0, SPSS Inc., Chicago, IL, USA), ukitumia uchambuzi wa Anova wa njia moja (one-way ANOVA) na mtihani wa Tukey's Honestly Significant Difference (HSD) kwenye kiwango cha umuhimu $p <0.05$. Data zote ziliwasilishwa kwa kutumia wastani wa vipimo ± kipimo cha kawaida. Uchambuzi wa Faktori za Kimsingi (PCA) ulifanywa kwa kutumia programu ya R (Timu ya R Core) kuchunguza uhusiano kati ya sampuli na sifa, na uchambuzi wa ufafanuzi wa wastani wa Quadratic (PLSR) ulifanywa kwa kutumia programu ya Unscrambler X, Toleo la 10.4, kuchunguza uhusiano kati ya data ya maelezo ya kina na data ya watumiaji.

Matokeo: Matokeo yalionesha tofauti kubwa katika muundo wa lishe wa muundo tofauti wa tambi ikilinganishwa na sampuli ya kudhibiti. Kuongeza unga wa majani ya Mlonge na unga wa dagaa kuliongeza protini ghafi na maudhui ya madini, kama vile chuma, kalsiamu, magnesiamu, na zinki. Mwonekano wa lishe wa tambi uliboreshwa kwa njia chanya; ikionesha kuwa kuongeza unga wa majani ya

Mlonge na unga wa dagaa hufanya bidhaa ya mwisho kuwa na thamani zaidi kiafya. Kwa msingi wa nyenzo kavu, protini ghafi ilikuwa kati ya 11.76-21.40g/100g, nyuzinyuzi ghafi 0.00-0.02g/100g, mafuta ghafi 1.89-2.94g/100g, majivu 1.38-2.26g/100g, wanga 62.31-74.29g/100g, na nishati 358.50-364.53 kcal/100g. Muundo wa madini ulionyesha chuma kati ya 32.55-65.50mg/100g, kalsiamu 7.39-66.61g/100g, magnesiamu 28.86-87.35mg/100g, na zinki 2.21-39.25mg/100g. Kwa hiyo, kuongeza unga wa majani ya Mlonge na unga wa dagaa kulionyesha uwezekano wa kuongeza thamani ya lishe ya tambi.

Ilijulikana kuwa kuongeza unga wa majani ya Mlonge na unga wa dagaa kuliondoa ugumu na ushirikiano, kufanya tambi kuwa laini na isiyoshikana zaidi kadri viwango vya unga vilivyokuwa vikiongezeka. Zaidi ya hayo, upotevu wa kupikia, ongezeko la kiasi, na upokeaji wa maji vilichunguzwa, na kuonesha kuwa viwango vikubwa vya unga hizi zilisababisha upotevu mkubwa wa upishi na kiasi kidogo cha ongezeko la kiasi na upokeaji wa maji, ambayo ilikuwa na athari kwenye muundo na uwezo wa kushikilia maji wa tambi. Tathmini za hisia pia zilifanywa, na kudhihirisha kuwa viwango vikubwa vya unga wa majani ya Mlonge na unga wa dagaa vilisababisha mabadiliko katika sifa za hisia za tambi, na viwango vidogo kwa ujumla vikipokea alama za kukubalika zaidi. Kwa kuongezea, uchambuzi wa maelezo ya kiasi ulionesha kuwa kuongeza unga hizi zilisababisha mabadiliko katika sifa maalum za tambi, kama vile rangi, harufu, chumvi, na ugumu, na mabadiliko makubwa zaidi kwenye viwango vikubwa vya unga.

Hitimisho: Utafiti huu unaonesha kuwa kuongeza unga wa majani ya Mlonge na unga wa dagaa kwenye muundo wa tambi inaweza kuwa njia inayofaa ya kuboresha muundo wao wa lishe. Hata hivyo, kuzingatia kwa makini athari za hisia na usawa unaohitajika kati ya lishe na sifa za hisia ni muhimu. Wazalishaji wa kiwango kidogo nchini Tanzania wanaweza kutumia ufahamu huu kuboresha tambi zinazovutia sio tu kwa lishe lakini pia kwa watumiaji, na hivyo kuchangia kuboresha chaguzi za chakula na labda kutatua changamoto za lishe. Kwa muhtasari, utafiti huu unatoa ufahamu muhimu katika njia inayofaa ya kuboresha ubora wa lishe ya vyakula vinavyotumiwa kawaida, na kuleta manufaa kwa tasnia ya chakula na watumiaji nchini Tanzania.

DECLARATION

I, **VICTORIA THOBIAS MPALANZI**, 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 in any other institution for a degree award.

____________________________ ________________________

Victoria Thobias Mpalanzi Date

(MSc. Candidate, Food Quality and Safety Assurance)

The above declaration is confirmed by;

____________________________ ________________________

Dr. Davis Naboth Chaula Date

(Supervisor)

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Dr. Alex Wenaty Date

(Supervisor)

LIST OF PUBLISHED AND SUBMITTED PAPERS

Paper 1: Proximate and Mineral Composition of Noodles Incorporated with Moringa and Sardine Powders
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DEDICATION

I lovingly dedicate research work to my cherished family members: my father, Thobias Mpalanzi, my mother, Annastansia Msegeya, my sister Caroline Mpalanzi, my younger sisters, Gloria Mpalanzi, Macklina Mpalanzi and my brother George Mpalanzi

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LIST OF ABBREVIATIONS AND ACRONYMS

^0C:	Degree Celsius
AOAC:	Association of Official Analytical Collaboration
CODEX:	Codex Alimentarius Commission
EAS:	East African Standards
FAO:	Food and Agriculture Organization
G:	Gram
ICP-OES:	Inductively Coupled Plasma Optical Emission Spectroscopy
Kg:	Kilogram
LMICS:	Low and Middle Income Countries
Mg:	Milligram
Ml:	Millilitre
p- value:	Observed significance level
WHO:	World Health Organization
mJ:	Milijoule
mm:	millimeter

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background Information

Noodles are staple foods of many countries worldwide, which can be made from a vast range of flour, including wheat, rice, maize and potato, using extruder machines by adding flavourings like eggs and spices (Huang and Lai, 2010). Most are made from wheat flour, starch, water, salt, sodium carbonate, and other ingredients that improve the texture and flavour of noodles, such as cinnamon and curry powder (Yousif *et al*., 2012).

Consumers are highly demanding since they play a significant role in human beings' nutritional and societal value (Li *et al*., 2014). Despite the two reasons, also its consumption has increased globally because of its unique flavour and taste, longer shelf life, reasonable price and convenience

According to East African Standard (EAS 173:2000), pasta products-specification (macaroni, spaghetti, vermicelli), noodles should be in solid rods of minimum length 250 mm and diameter between 1.25 mm and 2.0 mm and moisture content should not be more than 10% m/m.

Niu and Hou (2020) postulate that noodles are classified into several types based on different processing technologies, including fresh raw noodles, dried noodles, parboiled noodles, frozen noodles, steamed noodles, and instant noodles. Fresh raw noodles are prepared without drying and have a moisture content of around 32%-38%. Dried noodles are much lower in moisture content due to the drying process, thus contributing to a longer shelf life. Parboiled noodles are produced by partially cooking raw noodles in water, which increases their moisture content; frozen noodles consist of both frozen raw and frozen cooked noodles; steamed noodles are cooked in a steamer, and instant noodles consist of fried and air-dried noodles.

Noodles often lack essential nutrients, such as vitamins, minerals, and dietary fiber, due to the refining process involved in their production. According to a study by Mahmud *et al.* (2023), refined wheat flour, the primary ingredient in most noodles, is deficient in essential nutrients compared to whole wheat flour, leading to nutritional inadequacies in noodle products. Additionally, prolonged consumption of nutritionally deficient foods like noodles can contribute to various health risks, including micronutrient deficiencies, cardiovascular diseases, and metabolic disorders. Furthermore, World Health Organization (WHO, 2019), postulate that inadequate intake of essential nutrients increases the risk of malnutrition-related health issues, compromising overall health and well-being.

In Tanzania, where noodles are a popular staple food, the prevalence of nutritional deficiencies is high due to the consumption of inadequately fortified noodles which poses a significant public health concern. A study by Ekesa et al. (2018) highlighted the need for interventions to enhance the nutritional quality of staple foods like noodles to address malnutrition and improve public health outcomes in Tanzania.

Although cereal-based noodles are frequently consumed, they are low in protein content and lack some of the nutrients such as fibre, antioxidants and fats, which are often enhanced with additives such as protein supplements, emulsifiers, edible gums, antioxidants, and preservatives to counteract the deficiencies and to improve flavour, taste, appearance and nutritional profile of noodles (Hussin *et al*., 2020). Also, wheat flour that is mainly used can be supplemented with other ingredients to enhance the nutritional value of noodles to be produced, and such supplements can be of both animal origin and plant origin, for example, Bambara groundnuts (*Vigna subterranea*), moringa (*Moringa oleifera*), fish, and oats

Sardine, also known as “dagaa” in the lake, is the smallest fish with the highest nutritional and economic value (Isaacs, 2016). In Tanzania, Lake Victoria, located in the equatorial region of east Africa in the Mwanza region, supplies approximately 55% of all fish consumption in Africa, with sardines accounting for more than half of the lake’s total yearly catch (dagaa). Tanzania is the largest contributor of sardines among the three countries bordering the lake (Tanzania, Kenya and Uganda), with 433,845 tons landed in 2015, compared to 289,873 tons in 2010. (Mkunda *et al*., 2020)

Sardine is an imperative food of excellent nutritional value as itgives high-quality protein, unsaturated fatty acids, vitamins A, D and vitamin B family and assortments of minerals including calcium, copper, zinc, iron and iodine needed for physical and mental improvement (Owaga *et al*., 2010). Furthermore, Bundala *et al.* (2020) argue that the protein contribution of sardine is almost similar to that of eggs and greater than the individual contributions of pig meat, poultry meat, bovine meat and goat. Calcium is required for the growth, development, and maintenance of healthy bones and teeth, as well as nerve and muscle function. Zinc is essential for normal growth, development, and neurological function. Vitamin A is required to grow and maintain healthy skin, eyes, and immune systems (Pal *et al*., 2018).

Each food’s macronutrient and micronutrient content varies globally, and some foods lack enough micronutrients to meet the recommended dietary intake, whereas micronutrients are required for various essential roles; for example, iron helps to prevent anaemia, but iodine is especially important for children’s growth and development (Lutter and Rivera, 2003).

According to Kawarazuka and Béné (2011), sardine was used to supplement many foods to increase nutrient levels of foods that had lower macronutrient and micronutrient levels than what was required due to its high amount of both macronutrients and micronutrients. Moringa (*Moringa oleifera*) is a plant species in the moringaceae family. *Moringa oleifera* plants were originally found in Sub-Himalayan India, Pakistan, Bangladesh, and Afghanistan, and they have been widely used as a traditional medicine by ancient Romans, Greeks, and Egyptians for centuries (Fathil, 2022). This plant has recently spread to other countries, including India, Ethiopia, the Philippines, Sudan, and East Africa (Ebert, 2014). Moringa tree is known by many different names in different parts of the world, including benzolive, drumstick tree, horseradish tree, kelor, marango, mlonge, mulangay, sahijan, and sajnaas (Dixit *et al*., 2016).

Moringa oleifera is known in Tanzania as “mlonge” in Swahili. Mostly found in Tanzania, including Morogoro (Gairo inland plateau) and the Ruvu coastal region (Chamshama *et al*., 2014). According to Hussin (2020), moringa grows in tropical and subtropical climates, is drought resistant, and can even grow in a variety of less fertile soils with soil pH ranging from 4.5 to 9.0. *Moringa oleifera* is a nutrient powerhouse due to its high nutritional content (Chhikara *et al*., 2020). Each part of the plant has edible value, as roots and barks are raw materials used to make traditional medicines, seeds act as storage of edible vegetable oils, and leaves are the most nutritious part of the plant, contribute to both micro and macronutrients as well as bioactive elements (Gopalakrishnan *et al*., 2016; Prayitno *et al*., 2021).

Despite all nutritional benefits, it was reported (Kakde *et al*., 2018; Sodamade *et al*., 2013) that moringa has the effect of improving immunity, anti-inflammatory, antiulcer, antibacterial, antifungal analgesic, preventing and treating diabetes, hypertension and other effects. Hence it is widely applied in medical and health care.

According to Adi et al. (2019), Moringa is a good supplement to staple foods like noodles because of its incredible nutritional value. This was also supported by a study conducted by Zhang *et al*. (2017), which found that daily consumption of 25 g of Moringa leaves dry powder provided the body with 42% protein, 125% calcium, 61% magnesium, 41% potassium, 7l% iron, 272% vitamin A, and other nutrients. Furthermore, 100 g of leaves contains twice as much protein and calcium as a cup of milk and twice as much vitamin C as an orange, which improves the health of people who are malnourished or lacking in protein.

1.2 Problem Statement and Justification

Tanzania is among the developing countries which suffer from malnutrition problems. Although different measures have been taken to combat malnutrition, the situation is still severe. Different malnutrition studies have been conducted mostly for children below 5 years, neglecting the adolescent group in nutrition programming and the small number of research and intervention efforts being done while these groups also have the problem of malnutrition (Rector *et al*., 2021). The problem of malnutrition (both conditions including undernutrition and micronutrient deficiency) is a critical challenge among adolescents in Tanzania, both girls and boys, as the study done by (Pangani *et al*., 2016; TACAIDS, 2011) shows that adolescent girls 18% are underweight and 47.3% are anaemic together with adolescent boys who suffer the significant burden of malnutrition with 13% to 17% being overweight and 10% having underweight or iron deficiency.

According to WHO (2018), most adolescent deaths occur in both low- and middle-income countries in Africa, where poor dietary intake is the main source of inadequate amounts and proportions of energy, protein, vitamins and minerals associated with micronutrient deficiencies.

However, the nutrients which they lack includes iron deficiency anaemia, folic acid, vitamin A and vitamin B12, calcium, zinc and vitamin D, diarrhea diseases, high fasting plasma glucose, high blood pressure, preconception nutrient deficiencies. Additionally, in Mozambique, Senegal, Cambodia, India and Haiti, micronutrient deficiency, especially iron, is at a higher rate, approximately 40% or above among adolescent girls aged 15-19 years (WHO, 2018). Despite poor dietary intake, dietary patterns such as snacking, usually on energy-dense foods; meal skipping, especially breakfast; or irregular meals; the widespread use of fast foods and easy-to-prepare foods; and low utilization of fruits and vegetables all contribute to adolescent malnutrition (Omage and Omuemu, 2018). Furthermore, Dixit *et al*. (2014) discovered that more than two-thirds of adolescents in Nepal choose fast food (ready-to-eat snacks, chips, etc.). Further, much of the diet in Tanzania consists of starchy foods, including maize, cassava, rice, wheat, and sweet potatoes, contributing to an overall poor-quality diet.

According to Dhir and Singla, (2019), the consumption of instant noodles in Tanzania has been steadily increasing over the past few years. Between 2016 and 2020, the annual growth rate of instant noodles consumption in Tanzania was estimated to be around 6.5%. Furthermore, The Tanzania Food and Nutrition Centre (TFNC) reports that malnutrition rates remain a significant public health concern in Tanzania, particularly among children under five years of age and women of reproductive age. According to the Tanzania Demographic and Health Survey (TDHS) 2015-2016, approximately 34% of children under five in Tanzania are stunted, 21% are underweight, and 5% are wasted (TFNC, 2020).

The dietary patterns in Tanzania are characterized by a heavy reliance on staple foods such as maize, rice, and cassava, which may lack adequate micronutrients. A study by Muto *et al*. (2023) found that traditional Tanzanian diets are often deficient in key vitamins and minerals, contributing to the high prevalence of malnutrition in the country.

According to Pakhare *et al*. (2018), noodles are a starchy staple food high in carbohydrates without cholesterol, low in sodium and fat, but low in protein and key amino acids. This exposes the consumer at risk for malnutrition-related disorders such as insulin resistance, micronutrient deficiency, and hypoglycemia. According to different research, noodles were reported to be a health risk among different people as they lack protein, fibre, vitamins A, C & B12, calcium, magnesium and potassium. Additionally, they lack antioxidants and phytochemicals, which affect health (Bata *et al*., 2021). Similarly, Roos *et al*. (2019) argue that noodles have also been found to increase health risks to pregnant women, nursing mothers, school-going children and adolescents due to lack of protein and other micronutrients.

Nowadays, consumers all around the world are more at risk of many diseases, such as diabetes due to obesity, high cholesterol, cardiovascular diseases, high blood pressure and irregular blood sugar levels. These risk factors are caused by an unfit diet low in essential nutrients like dietary fibre, protein, and micronutrients. Some studies have shown that regular consumption of noodles is associated with poor overall diet quality, and noodle consumers were found to have a significantly decreased intake of protein, calcium, vitamin C, phosphorus, iron, niacin, and vitamin A. They also had an increased intake of sodium and calories (Park *et al*., 2011).

This study aims to develop noodles incorporated with fish (sardine) and moringa leaves, which will enhance or boost the nutritional content of noodles because sardines and moringa leaves have high-nutritional value. These easily digestible proteins contain all essential amino acids (AA) necessary for healthy human diets and are high in micronutrients such as folate, zinc, calcium, vitamin A, iron, and B vitamins and fats. Also, the protein that will be obtained from sardine and moringa leaves is more economical than high-priced meat protein and will help to reduce the incidence of malnutrition. The study developed noodles incorporated with sardine and moringa leaves that will enhance the nutritional content of noodles. Besides increasing the nutritional value of noodles by utilizing *Moringa oleifera* leaves, this research will also promote the use of sardines through product diversification.

1.3 Study objectives

1.3.1 General objective

To improve the nutritional content of noodles produced by small scale processors through the incorporation of sardines (dagaa) and *Moringa oleifera* leafs

1.3.2 Specific objectives

i. To determine the nutritional quality of composite noodles, including proximate and micronutrient composition.
ii. To evaluate the acceptability of developed composite noodles.
iii. To assess the physiochemical properties of the developed composite noodles, including texture profile and cooking qualities

1.3.3 Research questions

i. What is the proximate and mineral composition of noodles incorporated with moringa and sardine powders?
ii. how acceptable are these noodles in terms of sensory perception?
iii. what are the effect on cooking quality and texture profile of composite noodles upon incorporation of moringa and sardine powders?

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 present the published papers, whereas Chapter four presents the general discussion and Chapter five the general conclusion and recommendations.

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CHAPTER TWO

Manuscript One

Proximate and Mineral Composition of Noodles Incorporated with Moringa and Sardine Powders

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ABSTRACT

This study aims to investigate the effect of incorporating *Moringa oleifera* leaf powder and sardine powder into wheat-based noodle formulations on their nutritional composition. Different formulations were prepared with varying ratios, expressed in percentage (%): WM1 (99.6 wheat: 0.4 moringa), WM2 (99.2 wheat: 0.8 moringa) andWM3 (99 wheat :1 moringa); WS1 (95 wheat: 5 sardine), WS2 (90 wheat: 10 sardine), WS3 (85 wheat: 15 sardine) and the control sample (WC) containing 100% wheat was also included for comparison. The nutritional parameters assessed included crude protein, crude fiber, crude fat, ash, carbohydrate and energy content. Mineral compositions were also determined, including calcium (Ca), magnesium (Mg), iron (Fe) and zinc (Zn). The results demonstrated significant variations in the nutritional composition of the different formulations compared to the control sample. Results of proximate composition based on dry matter showed that the crude protein values ranged from 11.76-21.40g/100g, crude fibre values ranged from 0.00-0.02g/100g, crude fat values ranged from 1.89-2.94g/100g, ash content values ranged from 1.38-2.26g/100g, carbohydrate content values ranged from 62.31-74.29g/100g and energy values ranged from 358.50-364.53 kcal/100g. Furthermore, the minerals results showed iron values ranged from 32.55-65.50mg/100g, calcium values ranged from 7.39-66.61g/100g, magnesium values ranged from 28.86-87.35mg/100g and zinc values ranged from 2.21-39.25mg/100g. These results indicate that the fortification of noodles with moringa and sardine powders can be a viable approach for enhancing the nutritional value of the final product.

Keywords: Proximate composition, Micronutrients, Moringa leaf, Sardine, Recommended Dietary Intake.
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INTRODUCTION

Malnutrition remains a pressing global issue, particularly affecting vulnerable populations such as adolescents who are going through critical growth and development stages (Heslin and McNulty, 2023). Adequate nutrition during this period is crucial for their overall health and well-being, as well as for the prevention of various nutrition-related diseases (LeLeiko et al., 2022). Ronan et al. (2021) postulate that malnutrition significantly impacts human health and well-being as it leads to a range of health problems, including stunted growth, weakened immune systems, anemia, and a heightened susceptibility to various diseases. Malnutrition can impair the physical and cognitive development of adolescents, having a long term effect on their health and productivity.

The world faces the largest cohort of adolescents, aged between 10 and 19 years, with approximately 90% of these adolescents residing in low- and middle-income countries (LMICS). In many of these countries, adolescents often enter this critical stage of development thin, stunted, anemic, and micronutrient deficient (Madjdian et al., 2018). These conditions can be attributed to a variety of factors, including limited access to nutrient-rich foods, economic constraints, and wrong dietary choices, which are more prevalent in low- and middle-income countries (Kavle and Landry, 2018). The study done by Mrimi et al. (2022) showed that in Tanzania, adolescents are affected by malnutrition. Though this is underreported, little has been done to improve the health and nutritional status of adolescents.

Furthermore, Nicholaus et al. (2020) postulate that in recent years, innovative approaches have been explored to address malnutrition, and one such approach involves the development of nutrient-rich food products using materials which are high in nutrients. Examples are sardine, seaweed, beans, chickpeas as well as vegetables, such as carrots and leafy greens.

Noodles are a popular staple food consumed by millions of people worldwide due to their convenience, affordability, and versatility (Akubor, 2023). However, the basic composition of traditional noodles often lacks essential nutrients required for optimal nutrition, which can be particularly problematic for vulnerable populations, such as children and adolescents (Ikbal et al., 2022). In many low- and middle-income countries, noodles are a widely consumed and accessible source of calories, but they lack key nutrients. This can exacerbate the malnutrition issue among adolescents in these regions, as these individuals rely on noodles as a significant part of their diet.

In Tanzania, noodles are a commonly consumed food due to their affordability and ease of preparation. They serve as a quick and convenient meal option, especially for individuals with busy lifestyles, such as university students (Noort et al., 2022). Also, Ang et al. (2020) argue that noodles are readily available in various forms, including instant and non-instant versions, making them a popular choice among people of all age groups. Despite their convenience, the basic composition of these noodles often falls short in terms of nutritional value (Adejuwon et al., 2020).

Vishwakarma et al. (2022) argue that, in recent years, there has been growing interest in fortifying food products with nutrient-dense ingredients to combat malnutrition effectively. *Moringa oleifera*, a plant commonly found in tropical and subtropical regions and often referred to as the "miracle tree," is recognized and has gained significant attention for having rich nutrient contents, including vitamins, minerals and antioxidants. This makes it a better ingredient for food fortification (Cao et al., 2023). Also, this superfood has been extensively studied for its potential health benefits, including its ability to combat malnutrition and support overall growth and development (Islam et al., 2021). Similarly, Santos et al. (2023) supported that, sardines which are fatty fish rich in omega-3 fatty acids, protein, and various micronutrients, have shown promising nutritional advantages in improving overall dietary quality.

Carpentieri et al. (2022) postulate that, the incorporation of natural nutritional components in wheat noodles could be a better option and in day to day requirements. Many studies are investigating the possibility of fortifying noodles as an effective public health intervention and improving its nutritional attributes (Binou et al., 2022; Shubham et al., 2020). Therefore, enhancing the nutrient content of noodles could be a practical and effective way to address malnutrition in our locality.

To address these challenges, this study aimed to develop noodles incorporated with sardines and moringa leaf powders and investigate the proximate composition and mineral content of these innovative noodles. The proximate composition analysis will evaluate the levels of macronutrients, including protein, fats, carbohydrates, and dietary fiber. The mineral analysis will focus on essential elements, such as iron, calcium, zinc, and magnesium. These findings will provide valuable insights into the potential of incorporating moringa and sardines into noodles as a means of enhancing their nutritional value. The approach offers a practical and affordable solution to address adolescent malnutrition as well as provides evidence-based recommendations for such interventions to improve the quality of diets for adolescents.

MATERIAL AND METHODS

Samples collection

Moringa leaves were collected from Frida Home Steady Farms located in Morogoro Region. Dried sardines, cooking oil, salt, wheat flour and baking powder (sodium carbonate) were collected from Chief Kingalu Market at Morogoro Region, Tanzania.

Sample preparation

Preparation of moringa leaf powder

Moringa leaf powder was made according to the methods of Orisa and Udofia. (2019) and Kumar. (2021), with slight modifications . Moringa leaves Figure 1a) collected from the farm were sorted, with healthy leaves chosen for further processing and damaged leaves discarded. The selected leaves were washed with distilled water to remove all dirt and dust. The leaves were placed on perforated trays and widely spread for 20 minutes to drain excess water from them. After 20 minutes, trays were arranged on laboratory tables and dried for 4 days under shade until the moisture content reached 7%. After drying, the leaves were ground into a fine powder, as shown in Figure 2 with a high speed multifunctional crusher machine (model 750A). Then, the leaves were sieved through a stainless steel sieve with 500 µm. Then, the powder was packed in an airtight zipped bag to avoid absorption of the surrounding moisture which may degrade its quality and nutrients for further processing.

Preparation of sardine powder

Dried sardines, as shown in Figure 1b were prepared by removing their heads first. Then, the remaining parts of their bodies were washed with portable water to remove sand and other foreign matters. The sardines

Figure 1: Main ingredients used to make noodles.

Figure 2: Moringa leaf powder.

Figure 3: Sardine powder.

were spread on oven trays after being washed. Then, they were placed in an oven set at 60°C for them to dry. After 42 hours, the dried samples with moisture content of 10% were removed from the trays and ground into fine powder (Figure 3) using a high speed multifunctional crusher machine (model 750A). Then, they were sieved through a stainless steel sieve with 500 µm. Finally, the fine powder was sealed in airtight zipped bags and stored for further processing (Mamun et al., 2022).

Sample formulation and composition

The samples were combined in proportions that met the FAO/WHO energy and micronutrient requirement for adolescents aged 14-19 years using linear regression method. Six samples of noodles were formulated as indicated in Table 1. Thus, a total of seven samples were prepared including 1 control sample.

Dried noodle preparation

The dried noodles were prepared following the method described by Zula et al. (2021) as shown in Figure 4. The obtained moringa leaf powder and wheat flour (Figure 1C and Figure 2) were mixed in the following proportions: 100:0, 99.6:0.4, 99.2:0.8, and 99:1. Also, sardine powder and wheat flour were mixed in the

Table 1: Composition of noodles incorporated with moringa leaf powder and sardine powder (g/100g).

Ingredients	Formulation name	Ratios
Wheat flour	WC	100:0
Wheat flour + moringa leaf powder	WM1	99.6:0.4
	WM2	99.2:0.8
	WM3	99:1
Wheat flour + sardine powder	WS1	95:5
	WS2	90:10
	WS3	85:15

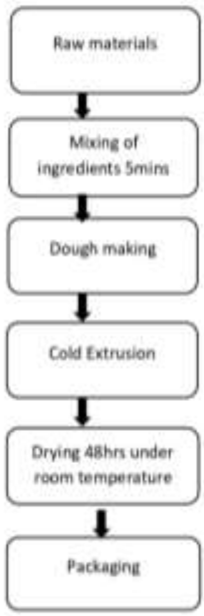

Figure 4: A flow diagram showing noodle preparation. Source: modified from Orisa and Udofia. (2019)

following proportions: 95:5, 90:10, and 85:15. They were measured using BOECO Germany analytical balance (Boeckel + Co BBL31 21505716 XX43-0035) before processing. After measuring those proportions, the composite flour was mixed for five minutes in Amasadora Spiral Mixer Heavy Duty 3 Speed Flour Dough Mixer Machine (model number SC-B30). Then, 300mls of water, 3g of salt, 2% cooking oil and 5g of sodium carbonate (baking powder) were added. They were continuously mixed to ensure that the dough had adequate consistency. The prepared dough was then placed in a laboratory extruder machine (China pasta making machine model number IT-IPM60) for the cold extrusion of desired shape noodles. Finally, the extruded noodles were cut into similar sizes and arranged on trays before drying at room temperature for

48 hours (2 days). Then, they were packed into zipped bags and stored at room temperature for about 25°C for further analysis and sensory evaluation.

Proximate and mineral composition

Crude protein

Crude protein in the samples was determined by Kjeldahl method of 981.10 (AOAC, 1998). 0.5 g of the dried samples was weighed and then transferred into a digestion flask. Ten (10) mL of concentrated H_2SO_4 and 8 g of digested mixture were added into the flask. The flask was swirled in order to mix the contents thoroughly. Then, the samples were digested using Tecator digestion system 40 (Model 1016 digester, Sweden) for 2 hours until the mixture became clear (blue green in color). The digest was cooled and transferred to 100 mL volumetric flask, in which distilled water was added up to the mark.
The digest was distillated, in which 10 mL of 0.5 N NaOH was gradually added through the same way. Distillation was continued for 10 min and NH_3 produced was collected as NH_4OH in a conical Erlenmeyer flask containing 20 mL of 4% boric acid solution with 3 drops of modified methyl red indicator. The distillate was then titrated against 0.1 N HCl (hydrochloric acid) until pink color appeared. The blank was also run following all the above steps.
The formula used to calculate the crude protein content of the samples was,

$$\%\, crude\ protein = 6.25 \times \%N$$

Where

$$\%\,N = \frac{(S-B) \times N \times 0.014 \times D}{weight\ of\ the\ sample\ (g) \times volume\ (mL)} \times 100$$

Crude fat

The crude fat of the samples was determined by ether extract method of 920.39, using soxhlet apparatus (AOAC, 1998). 5 g of moisture free sample was placed in fat free extraction thimble with cotton wool in the bottom. The thimble was covered by cotton wool on top and then introduced in the extraction tube. Weighed, cleaned and dried receiving beaker was filled with 60 mL of petroleum ether and fitted into the soxhlet apparatus. Water and heater were turned on to start the extraction. Three phases were accomplished in 55 min: the boiling phase for 15 min, fat extraction phase for 30 min and petroleum ether recovery phase for 10 min. Then, the cups were placed in an oven at 105°C for 10 min to evaporate the remaining petroleum ether. This was followed by cooling it in a desiccator for 20 min and weighed.

The percent of crude fat was determined by using the following formula:

$$\%\, crude\ fat = \frac{weight\ of\ ether\ extract(g)}{weight\ of\ dry\ samples\ (g)} \times 100$$

Crude fibre

A sample of 1.0 g was weighed and put in a porous crucible. The crucible was then placed in a dosi-fiber unit while the valve was left in the "OFF" position. After that, each column received 150 mL of warmed sulphuric acid (H_2SO_4) solution and a few drops of foam suppressor. The cooling circuit was then opened, and the heating elements were turned on (power at 90%). When it began to boil, the power was reduced to 30% and it was left for 30 minutes. To prevent the formation of acid salts, valves were opened for acid drainage and washed three times with distilled water to ensure full removal of acid from the sample. The same technique was utilized for alkali digestion, but instead of sulphuric acid (H_2SO_4), potassium hydroxide (KOH) was used as it is a suitable chemical for alkali digestion. The sample was dried in an oven at 150°C for 1 h. The sample was then allowed to cool in a desiccator before being weighed. The sample crucibles were kept in a muffle furnace at 550°C for 3 hours. After cooling in a desiccator, the sample was weighed again.
Calculations were done by using the formula:

$$\%\, crude\ fibre = \frac{weight\ of\ loss(g)}{weight\ of\ dry\ samples\ (g)} \times 100$$

Ash content

The ash content of the samples was determined according to AOAC (1998)'s method of 923.03. For the determination of ash, clean empty crucible was placed in a muffle furnace at 600°C for an hour. It was cooled in desiccator and then the weight of the empty crucible was noted. Five (5 grams) of each of one sample was taken in the crucible. Then, the crucible was placed in a muffle furnace at 600° C for 5 hrs. Grey white ash appeared, which indicates complete oxidation of all organic matter in the sample. The ashing furnace was switched off and the crucible with the sample was cooled and weighed.
Percentage of ash was calculated by the following formula:

$$\%\, Ash\ content = \frac{final\ weight\ (g) - crucible\ weight\ (g)}{weight\ of\ dry\ samples\ (g)} \times 100$$

Carbohydrate

The percentage of carbohydrate was calculated as percentage difference using the formula,

Table 2: Proximate composition (g/100g DM) and energy (kcal/100g) of dried noodles incorporated with moringa leaf and sardine powders.

formulation	Crude protein	Crude fibre	Crude fat	Ash	Carbohydrate	Energy
WC	11.67 ± 0.07^{a}	0.00 ± 0.00^{g}	2.12 ± 0.04^{k}	1.40 ± 0.04^{n}	74.29 ± 0.14^{t}	362.91 ± 0.67^{x}
WM1	11.49 ± 0.13^{a}	0.01 ± 0.00^{h}	1.92 ± 0.01^{k}	1.38 ± 0.06^{n}	74.27 ± 0.89^{t}	360.32 ± 3.09^{x}
WM2	12.42 ± 0.08^{b}	0.02 ± 0.00^{i}	1.89 ± 0.08^{k}	1.64 ± 0.01^{p}	72.96 ± 0.02^{t}	358.50 ± 0.42^{x}
WM3	16.38 ± 0.01^{c}	0.02 ± 0.00^{i}	2.63 ± 0.07^{l}	3.18 ± 0.01^{r}	67.61 ± 0.22^{u}	359.65 ± 0.20^{x}
WS1	14.84 ± 0.03^{d}	0.00 ± 0.00^{g}	1.99 ± 0.05^{k}	1.43 ± 0.00^{n}	71.28 ± 0.07^{v}	362.41 ± 0.58^{x}
WS2	17.00 ± 0.06^{e}	0.00 ± 0.00^{g}	2.82 ± 0.03^{lm}	1.79 ± 0.10^{p}	67.74 ± 0.60^{u}	364.53 ± 2.51^{x}
WS3	21.40 ± 0.06^{f}	0.01 ± 0.00^{h}	2.94 ± 0.10^{m}	2.26 ± 0.03^{s}	62.31 ± 0.23^{w}	361.29 ± 0.18^{x}

$$\%carbohydrate = 100\% - (\%protein + \%crude\ fat + crude\ fibre + \%\ ash)$$

Energy

According to Igbabul et al. (2018), Atwater's conversion factor method was used to calculate energy content. The percent calories in the selected samples were calculated by multiplying the percentage of crude protein and carbohydrate by factor 4 and crude fat by factor 9. The values were converted and expressed in kcal/100g.

$$energy\ content = (4 \times crude\ protein) + (4 \times carbohydrate) + (9 \times crude\ fat)$$

Mineral analysis

Analysis of minerals was carried out according to the method of Jachimowicz et al. (2021), with slight modifications. Samples were grounded using mortar and pestle to reduce particle size for them to be suitable for analysis, Then, they were sieved using a sieve with 1.18 mm. 0.5 g was weighed and placed in vials. 2mL (1:1) of nitric acid (HNO_3) and water were added to each sample for digestion. Then, 5 mL of (1:4) hydrochloric acid (HCl) and distilled water were also added and each of the vials was covered by watch glass. The samples were placed on hot block 150 (model: SC-154-240 S/N: 2022CECW5737 MFG DATE: 04/06/2022) at 95^{0}C and boiled for 30 minutes until they reached 85^{0}C . After reaching 85^{0}C, the samples were removed and cooled to room temperature. Distilled water was added up to 50 mL. Then, the samples were poured into a test tube and transferred to inductive coupled plasma optical emission spectrometry (Model Agilent 5900 SVDV ICP-OES, Serial number MY2215CP04, Software version 7.6.0.12121 and firmware version 5590) for detection of minerals.

Data analysis

All data of proximate and mineral compositions were analyzed using statistical software known as Statistical Package for Social Sciences (SPSS) version 25. One way analysis of variance (ANOVA) test was performed followed by a post-hoc test, Turkey (HSD) with significant difference being determined at a 5% level of significance ($p<0.05$). All results of all determinations were expressed as mean ± SD of duplicate values.

RESULT AND DISCUSSION

Values are expressed as mean± standard deviation. Mean values with different superscript letters along the column are significantly different at $p\leq0.05$. The following formulations were made:
WC (100% Wheat), WM1 (99.6%wheat: 0.4% moringa leaf powder), WM2 (99.2% wheat: 0.8% moringa leaf powder), WM3 (99% wheat: 1% moringa leaf powder), WS1 (95% wheat: 5% sardine powder), WS2 (90% wheat: 10% sardine powder), WS3 (85% wheat: 15% sardine powder).

Crude protein

From the results presented in Table 2, it is seen that the protein content values of the dried noodles incorporated with moringa leaf and sardine powders ranged from 11.67g/100g to 21.40g/100g. The results portrayed that there was a significant difference ($p<0.05$) in the protein content of the dried noodles among all the samples, but it was not significantly different ($p>0.05$) in the control sample (WC) and samples with 0.4% of moringa leaf powder . The protein content increased in the control sample as the amount of moringa leaf powder increased, as shown in WM2 and WM3 samples. This increase in the protein content occurred because the noodles contained both the protein naturally present in the base ingredients and also that from the added moringa leaf powder. Although sample WM1 consisted of 0.4% of moringa leaf powder, it showed no significant difference in protein content with the control sample. This might be attributed to the small concentration of moringa leaf powder added to the wheat flour for the preparation of noodles.
As the sardine powder increased, the protein content of the noodles also increased from 14.84g/100g to 21.40g/100g. The increasing trend in the protein content can be attributed to the protein-rich nature of sardine powder, which adds additional protein to the noodles when incorporated into the manufacturing

process. Current studies show that there was a significant increase in the protein content of the noodles containing moringa leaf and fish powders. These results support the study conducted by Orisa and Udofia (2019), who reported the increase of protein content of noodles incorporated with moringa leaf powder, cowpea flour and acha flour. The research conducted by Manaois et al. (2013) proved that, the protein content of rice cracker increased after the addition of 1% of moringa leaf powder. Another comparable study of Wani et al. (2013) indicated that, the substitution of cauliflower leaf powder resulted in a substantial increase in the protein content of noodle samples. Monteiro et al. (2016) researched on Nutritional Profile and Chemical Stability of Pasta Fortified with Tilapia (*Oreochromis niloticus*) and revealed there was increase in the protein content as the concentration of tilapia fish powder increased.

The protein recommended limits set by CODEX (2006) for adolescents are 46 g/100g for females and 52g/100g for males. In this study, the amounts of protein increased, but based on the recommended values, they all were below the limits. So, in order to meet the recommended levels, the concentrations of moringa and sardine powders should be increased to 5%, 10%, 15% and 20%, 25% and 30%, respectively.

Crude fibre

The results from this study (Table 2) show that the amount of crude fibre increased as the amount of moringa leaf and sardine powders increased. Noodle samples with moringa leaf powder had higher fibre content compared to the control sample (WC) and noodles with sardine powder (WS1, WS2 and WS3). This could be attributed to the addition of moringa leaf powder to the wheat flour, which is rich in both soluble and insoluble dietary fibers. Also the increase in the fibre content depends on the concentration of moringa leaf powder added. As the concentration increased, the fibre content also increased. Table 2 shows that there was no significant difference between the control sample (WC) and samples with 5% (WS1) and 10% (WS2) of sardine powder ($p>0.05$) in terms of their fibre content . This is because sardines are not known to be a significant source of dietary fibre, but they are rich in protein and omega-3 fatty acids; their fiber content is relatively low compared to other food sources (Poggioli *et al.*, 2023). In order to increase the fibre content in noodles, alternative sources of fiber, such as whole grains or fiber-rich vegetables could be considered instead of relying on sardine powder. Similar results were observed in a study conducted by Zula et al. (2021) on Proximate Composition, Antinutritional Content, Microbial Load, and Sensory Acceptability of Noodles Formulated from Moringa (*Moringa oleifera*) Leaf Powder and Wheat Flour Blend, It was discovered there was increase in fibre content upon the addition of moringa leaf powder in the noodles samples. Sengev et al. (2013), who studied the effect of moringa leaf supplementation on some quality characteristics of wheat bread, postulate that, the amount of fibre content increased as the amount of moringa leaf powder increased.

According to CODEX (2006), the recommended dietary fibres are 25.2g/100g for females and 30.8 g/100g for males. Based on the findings, sardine and moringa powder contributed a small amount of fibre as all samples were below the recommended amount.

Crude fat

The fat content of the dried noodles ranged from 2.12g/100g to 2.94g/100g; noodles with 15% of sardine powder were high in fat content compared to the other samples. There was no significant difference between the control sample and samples with 0.4% and 0.8% moringa leaf and 5% sardine powder ($p>0.05$) in terms of their fat content. Noodles with 10% and 15% of sardine powder had high values of fat contents. As the concentration of sardine increased, the amount of fat content also increased. This can be attributed to the fact that sardines themselves are a rich source of fat particularly in the form of omega-3 fatty acids. As the fat from the fish was transferred to the noodles, their overall fat content increased. Also, the increase in the concentration of moringa leaf powder resulted in increased amount of fat content from 2.12g/100g for the control sample to 2.63g/100g for WM3 sample containing 1% of moringa powder. Khan et al. (2023) reported similar results. The addition of moringa leaf powder in the whole wheat flour showed a significant increase in fat content, which ranged from 2.03 to 3.63% based on the supplementation ratios from 2.5 to 10% of moringa leaf powder. Omeire et al. (2014) postulate that, there was an increase in fat content (1.39-3.00%) in noodles produced with wheat, acha and soybeans composite flours. Furthermore, Chude et al. (2018) found an increase in fat contents in noodles with increased Bambara groundnut in wheat. Monteiro et al. (2016) reported there was increase in fat contents in noodles as the amount of fish increased.

Ash

Ash content in food refers to the inorganic residue left behind after complete combustion of organic matter. It is also an indicator of the mineral elements in the particular food sample. Results of the study show that there was no significant difference between the control sample (100% WC), WM1 (0.4%) and WS1 (5%) at $p>0.05$ degree of significance in terms of their ash content. Also, WM2 (10) and WS2 (10%) samples showed no significant difference in ash content at $p>0.05$. There was a significant difference in ash content between sample WM3 (1%) and WS3 (15%) at $p<0.05$. Substitution of 0.4% of moringa leaf powder into wheat flour showed no significant difference with the control sample at $p>0.05$. This might be attributed to the small concentration of moringa leaf powder used. As the concentration of moringa leaf powder increased the ash content increased since the noodle sample with 1% of moringa leaf powder (WM3) had higher mean value (3.18g/100g) of ash content compared to all the other samples. This can be due to the addition of moringa leaves which are known to be rich in minerals essential for plant growth and development, such as calcium, potassium, magnesium, and phosphorus. Also, noodles incorporated with sardine powder showed an increase in ash content as the concentration of sardine powder increased. This might be due to the presence of inorganic minerals in sardines, including calcium, magnesium and potassium, which increased the overall ash content when incorporated into wheat noodles. These results are comparable with Effiong et al. (2018), who reported the increase in ash content in noodles made with wheat and orange-fleshed sweet potatoes. Chude *et al.* (2018) reported that the substitution of fermented Bambara groundnuts in wheat noodles resulted in increased ash content of noodles from 1.80-3.08%. Ahmad et al. (2022) found an increase in the ash content of value-added noodles produced by fenugreek seed powder, which ranged from 0.9-3.12g/100g.

Carbohydrates

It is further shown that the amount of carbohydrates in the noodle samples decreased from 74.29g/100g to 62.31g/100g (Table 2). The control sample (WC) contained a high amount of carbohydrates compared to the other samples, although the difference was not statistically significant in samples with 0.4% and 0.8% of moringa leaf powder at $p>0.05$ level of significance. This might be due to the small concentration of moringa leaf powder incorporated into the wheat flour during the processing. The amount of carbohydrates decreased as the amount of moringa leaf and sardine powders increased. This could be attributed to the inclusion of the supplements, which are low in carbohydrates in wheat flour, resulting in the dilution of the carbohydrates present in wheat flour. Thus, the higher the concentration of these powders, the greater the dilution effect. This results in a decrease in carbohydrate contents. These results abide with those of Igbabul et al. (2018), who reported a decrease in carbohydrate contents in cookies produced with wheat, sweet detar (The underutilized species of tree legume that grows naturally in the drier regions of West and Central Africa has a wide range of uses due to its medicinal properties, edible fruit, and flour) and moringa leaf flour blends. A similar decrease in carbohydrate contents was observed in a study conducted by Hussin et al. (2020) on the effect of including Bambara groundnuts and moringa leaf powder in wheat flour for making noodles. Handayani et al. (2022) reported that the inclusion of moringa leaf powder resulted in decreased carbohydrate contents of pasta.

The carbohydrate content limit set by CODEX (2006) for adolescents is 130g/100g. The values of carbohydrates in all samples incorporated with sardines and moringa leaf powders were below the recommended limits.

Energy

The study results show that, the energy content of noodles ranged from 358.5-364.35kcal/100g (Table 2). The difference in energy contents among all the samples was observed, but the difference was not statistically significant at $p>0.05$. Noodles incorporated with moringa leaf powder showed a decrease in energy contents compared to the control sample. This is because moringa leaves are not rich in fat contents as well as carbohydrate contents compared to the wheat flour. Sample (WS2) which consists of 10% of sardines had the highest energy value of 364.35kcal/100g than all the other samples because of the high fat content derived from sardines; its carbohydrate content was not very low compared to sample (WS3) with 15% of sardine powder. Similar results are shown by Ndife et al. (2014), who reported increase in energy content in cookies with increase of full-fat soya in wheat flour. Furthermore, these results are comparable with those of Gomaa et al. (2023), who reported a decrease in the energy content of instant noodles with increase in moringa leaf and mushroom powders.

MINERAL COMPOSITION OF NOODLES

Values are expressed as mean± standard deviation. Mean values with different superscript letters along the column are significantly different at $p\leq0.05$. The following formulations were made:

WC (100% wheat), WM1 (99.6% wheat: 0.4% moringa leaf powder), WM2 (99.2% wheat: 0.8% moringa leaf powder), WM3 (99% wheat: 1% moringa leaf powder), WS1 (95% wheat: 5% sardine powder), WS2 (90% wheat: 10% sardine powder), WS3 (85% wheat: 15% sardine powder).

Calcium

According to Ali (2023), calcium is an essential mineral for the human body. It plays a crucial role in maintaining bone health, nerve function and muscle function. Incorporating calcium-rich ingredients in food products can be an effective way to enhance the nutritional value of food and provide consumers with additional health benefits (Bourassa et al., 2022).

The findings in Table 3 show that the calcium content of noodles ranged from 7.39- 66.61 mg/100g. The amount of calcium differs significantly among all the samples at $p<0.05$. For the noodles incorporated with moringa leaf powder, the amount of calcium increased as the concentration of moringa leaf powder increased

Table 3: Mineral composition of noodles incorporated with moringa and sardine powders (mg/100g)

Sample	Ca	Fe	Mg	Zn
WC	7.39±0.05[a]	32.55±0.07[f]	28.86±1.21[n]	2.21±0.01[u]
WM1	9.21±0.02[b]	34.45±0.21[i]	33.85±0.92[op]	2.22±0.01[u]
WM2	11.21±0.04[c]	39.35±0.21[h]	42.5±0.00[pq]	2.31±0.01[u]
WM3	12.03±0.03[d]	40.25±0.21[k]	52.5±1.41[q]	3.93±0.03[v]
WS1	14.02±0.05[e]	42.60±0.14[k]	55.34±0.01[q]	14.65±0.07[x]
WS2	29.37±0.06[f]	51.75±0.49[l]	74.60±3.52[r]	27.55±0.06[w]
WS3	66.61±0.06[g]	65.50±0.42[m]	87.35±5.05[s]	39.25±0.07[y]

compared to the control sample (WC). The increase in calcium content could be attributed to the amount of calcium present in moringa leaf. Furthermore, the incorporation of sardine powder into wheat flour for noodle-making resulted in a significant increase in calcium content compared to 100% wheat noodles. Five percent (5%), 10% and 15% of sardines powder resulted in increased calcium content of 14.02mg/100g, 29.37mg/100g and 66.61mg/100g respectively. As the concentration of sardines increased, the amount of calcium increased. The increase of calcium content could be due to the addition of sardines, which are rich in calcium content and hence contributed to an increase. These findings are closely related to the earlier studies done by Prayitno et al. (2022), who found an increase in calcium content upon the addition of moringa leaf powder in the ratios of 5%, 10% and 15% in wheat flour for making wet noodles. Also, Govender and Siwela. (2020) reported that, calcium content was increased upon the inclusion of moringa leaf powder in white and brown breads. Similarly, Mamun et al. (2022) revealed that the inclusion of small marine pelagic fish powder in food results in increased mineral contents, including calcium, iron and zinc.

According to WHO (2006) and CODEX (2006), the recommended calcium limit is 1200mg/100g for adolescents. All formulations in this study show increase in their calcium contents except the control sample. However, they were below the recommended levels (WHO 2006; CODEX 2006). In order to meet the recommended levels, the combination of moringa leaf and sardine powders could be useful or the addition of supplementing materials which are rich in calcium, such as okra (77mg/100g), soy bean (277mg/100g) and parsley (138mg/100g calcium) (Gomes et al., 2022).

Iron

The findings of the study showed that the inclusion of moringa leaf and sardine powders resulted in increased amount of iron content (Table 3). There was a significant difference in iron content among all samples compared to the control sample at $p<0.05$. Although the use of 0.8% and 1% of moringa leaf powder showed no significant difference in iron content at $p>0.05$, but the control sample and 0.4% moringa leaf powder showed difference. Iron content ranged from 32.55-65.50mg/100g and such increase could be attributed to the addition of supplements (moringa leaf and sardine powders) which are known to be rich in minerals, including iron (Gomaa et al., 2023). These results abide with the study done by Desai et al. (2018), who found an increase in iron content in pasta through the incorporation of protein powder from fish. These results also are in accordance with another current study of Roni et al. (2021), who revealed an increase of iron content amounting to 42.59mg/100g in fortified cake; it is higher than the unfortified cake. So this proves that the fortification of wheat flour with moringa leaf powder results in increased iron content, which is highly important to anemic people. In our previous study, it was found that noodles fortified with moringa (at 0.4%) had good cooking quality, sensory attributes and acceptability (Mpalanzi et al., 2023). Thus, the products can contribute to combat the hidden hunger. Generally, iron deficiency is a common health concern worldwide; therefore, using these natural sources to enhance the iron content of a food product or supplement could have potential benefits, especially for individuals at risk of iron deficiency, including adolescent girls.

Iron content limit set by WHO (2006) and CODEX (2006) for adolescent females is 15mg/100g and for males it is 11mg/100g. From the results, all formulations incorporated with moringa leaf and sardine powders were above the recommended levels. So, these are good sources of iron and can be used for the fortification of different food products, which can help people with anemia, especially adolescent girls who are prone to iron deficiency.

Magnesium

From the results in Table 3, wheat-based samples showed a gradual increase in magnesium contents as the concentration of moringa leaf powder or sardine powder is added to the wheat. The WC sample, which represents 100% wheat, had the lowest magnesium contents of 28.86 mg/100g compared to the other samples. There was a significant difference in magnesium contents between the samples at $p<0.05$, although samples WS2, WM2 and WS1 showed no statistical differences in magnesium contents at $p>0.05$. Moving towards the samples with moringa leaf powder and sardine powder supplementation (WM1, WM2, WS1, WS2, WS3), there was a consistent and significant increase in magnesium levels. The highest magnesium content was found in WS3, with a remarkable quantity of 87.35mg/100g.The increase in magnesium can be attributed to the enrichment of the wheat-based samples with moringa leaf and sardine powders as both moringa leaf and sardine powders are known to be rich sources of magnesium. Moringa leaves are naturally abundant in this mineral, and the addition of moringa leaf powder to wheat-based products results in a proportional rise in magnesium levels. Similarly, sardine powder, derived from sardine fish, also contributes to the elevated magnesium content due to the inherent magnesium stores in the fish. These results abide with the study of Mamun et al. (2022), who revealed that the inclusion of small marine pelagic fish powder in food results in increased magnesium content. Govender and Siwela (2020) postulate that moringa leaf powders are rich in magnesium and adding them in bread resulted in significant increase in magnesium.

The set limits of magnesium for adolescents recommended by CODEX (2006) are 360mg/100g for females and 410mg/100mg/100g for males. Therefore, all formulations in this study were below the recommended amount.

Zinc

Zinc is another essential mineral required for numerous enzymatic reactions and it plays a pivotal role in supporting the immune system and promoting overall health (Patil et al., 2023). From the results, zinc content increased with the increase of moringa leaf and sardine powders concentration.

From the findings shown in Table 3, the control sample WC (100% wheat) consisted of 2.21mg/100g of zinc, which is small amount compared to other samples incorporated with sardine and moringa leaf powders. Although there was no significant difference in zinc content between the control sample, WM1 and WM2 at $P>0.05$, sample with 1% moringa leaf powder (WM3) and all noodle samples incorporated with sardine powder (WS1, WS2 and WS3) showed a significant difference in zinc content compared to the control sample at $p<0.05$ level of significance. Among the moringa-supplemented samples, WM3 showed the highest zinc content of 3.93mg/100g and this can be due to the high amount of moringa leaf powder used compared to samples WM1 and WM2. Furthermore, when sardine powder was introduced into samples WS1 (5%), WS2 (10%) and WS3 (15%), the zinc content significantly increased; WS3 exhibited the highest zinc content at 39.25mg/100g. The increase in zinc content can be attributed to the inherent zinc concentration present in both moringa leaf and sardine powders as they are recognized for their substantial zinc content and other minerals. So, the enriched zinc content in the supplemented noodle samples highlights the potential of moringa leaf and sardine powders as effective fortifying agents for boosting the zinc content in wheat-based foods. This contributes to improved nutritional value. These results abide with the study done by Simonato et al. (2021), who found an increase in zinc content as moringa leaf concentrations (5%, 10% and 15%) increased in pasta fortified with moringa leaf powder . Furthermore, Kamble and Bhuvaneshwari. (2018) revealed there was an increase in zinc content through the incorporation of moringa leaf; with the addition of 5% of moringa leaf, the highest zinc content found was 9.66mg/100g.

According to CODEX (2006), the limit levels for zinc content are 9 mg/100g for females and 11mg/100g for males. Based on the results obtained, the amounts of zinc were below the recommended levels for samples incorporated with moringa leaf powder (WM1, WM2 and WM3). Samples incorporated with sardine powder were above the limits.

CONCLUSION

This study demonstrates significant improvements in both the proximate and mineral composition of noodle samples. It shows the positive impact of incorporating sardines and moringa leaf powders into the noodles. By analyzing the data, it becomes evident that the addition of these powders led to increased levels of essential minerals, such as calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn). It also enhanced proximate parameters, including proteins, carbohydrates, fats, ash contents, and fibers.

The significance of these findings extends beyond the ordinary demonstration of improved noodle composition. This research addresses a critical problem: the deficiency of key nutrients in common food products. The study's innovative approach of fortifying noodles with moringa and sardine powders provides a practical solution to this problem, which is effectively enriching the nutritional content of these staples.

The impact of these findings on humans is profound. Health-conscious consumers and the broader public will benefit from these more nutritious and health-promoting food products. By consuming these fortified noodles, individuals can enhance their intake of essential minerals and proximate nutrients, thereby contributing to an overall improvement in public health.

In conclusion, this research highlights the potential of moringa and sardine powders as valuable fortificants for a wide range of food products deficient in nutrients. By significantly enhancing mineral and proximate content in noodles, it paves the way for similar innovations in the food industry, offering a practical means to address nutritional deficiencies and promoting the health and well-being of consumers.

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CHAPTER THREE

Manuscript Two

Textural, Cooking Quality and Sensory Acceptability of Noodles Incorporated with Moringa Leaf and Sardine Powders

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Textural, Cooking Quality and Sensory Acceptability of Noodles Incorporated with Moringa Leaf and Sardine Powders

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Authors' contributions

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

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ABSTRACT

Noodles with varying percentages of wheat flour, moringa leaf and Sardine powders were developed and tested for texture, cooking quality, and sensory qualities. Various formulations were used to make the noodle samples. Noodles with moringa leaf powder were developed using in the following wheat and Moringa proportions in percentage: 99.6:0.4 (WM1), 99.2:0.8 (WM2) and 99:1 (WM3). Noodle samples containing sardine powder were created in the following ratios: 95:5 (WS1), 90:10 (WS2), 85:15 (WS3), and 100:0 wheat flour.
Textural qualities of the noodle samples were measured, including hardness, cohesiveness, springiness and adhesiveness. The inclusion of moringa leaf powder and sardine powder resulted in a considerable reduction in hardness and cohesiveness when compared to the wheat control.

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The noodles became softer and less cohesive as the concentration of moringa leaf powder or sardine powder increased.
The noodle samples' cooking loss, volume increase and water absorption were also measured. Higher concentrations of moringa leaf powder or sardine powder resulted in greater cooking loss as well as lower volume and water absorption. This implies that the inclusion of these powders altered the texture and water-holding capacity of the noodles.
Additionally, sensory evaluations were performed to determine the acceptability of the developed noodles in terms of color, aroma, texture, taste and overall acceptability. The results revealed that when the concentration of moringa leaf powder or sardine powder increased the sensory properties of the noodles samples were altered. Lower concentrations of these powders were related with greater acceptance scores in general.
Specific characteristics of the noodles-, such as color, aroma, saltiness and hardness were evaluated using quantitative descriptive analysis. The results showed that adding moringa leaf powder and sardine powders altered these properties with larger concentrations causing more noticeable changes.

Keywords: Noodles; moringa leaf powder; sardine powder; cooking quality; textural properties and sensory attributes.

1. INTRODUCTION

Noodles are the basic meal derived from wheat flour that is widely consumed around the world due to their ease of preparation, low cost, availability and longer shelf life. They are produced by extruding wheat flour mixed with water and other components using an extruder machine, then cutting it into the desired shapes and drying it [1]. Wheat flour is frequently utilized because of its high gluten protein content and appealing white color, which contribute to the end product's good rheological, cooking and sensory qualities. Despite their widespread acceptance, they are not regarded as nutritious foods because they lack certain nutrients such as minerals, amino acids and dietary fibers [2]. As people become more concerned about their health, the demand for foods with higher nutritional value has increased, prompting many researchers to focus on the quality improvement of noodles through the incorporation of various functional ingredients derived from natural sources in order to obtain stable noodles with high nutritional value, health benefits, good sensory and cooking quality, good texture properties and cost-effective to consumers [3].

Moringa oleifera is an easily cultivable tree, which provides an effective remedy to malnutrition. Almost all parts of this plant are utilized due to its nutritional value and alleged medical characteristics such as anti-inflammatory, anti-cancer and anti-diabetic features [4]. The leaves of Moringa oleifera appear to have nutritional potential and its incorporation or fortification in staple foods is a cost-effective solution that may aid in solving the problem of micronutrient deficiencies and malnutrition, particularly women and children from rural areas as well as in boosting immunity [5]. Various studies suggest that moringa leaf is a good food fortifier, yet the acceptability and sensory aspects of foods decline as Moringa Leaf Powder dosage increases [6,7]. Moringa oleifera leaf is utilized in the fortification of many food products such as noodles, bread, biscuits and others but despite all of its advantages, it is still underutilized in several countries [8].

Sardines (Rastrineobola argentea) are known as "dagaa" in Tanzania and is one of the most important commercial fish species of Lake Victoria. They are a good source of high-quality proteins which play an important role in muscle development, tissue repair and immune system function [9]. Sardines are especially valued for their high level of omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [10], (Chaula *et al.*,2019) . These fatty acids are necessary for brain function, inflammation reduction, and heart health [11]. Sardines are also rich in a variety of vitamins and minerals, including vitamin D, vitamin B12, calcium, and selenium, which contributes to their nutritional [12]. Majumder and Balange [13] postulated that by incorporating sardine powder into dried noodles, significantly enhance it's nutritional profile but also the fine texture of the powder allows better integration into the noodle dough, resulting in a more uniform distribution of sardine flavor throughout the noodles and improvement of different parameters such as firmness, elasticity and overall mouthfeel of the noodles, making them more pleasing to eat.

Tzia *et al.* [14] define sensory evaluation as the scientific discipline that uses human senses to carefully evaluate sensory properties of food products such as taste, color, aroma, texture, and appearance in a controlled environment. Sensory quality analysis serves as a reference for understanding deviations from requirements and implementing necessary remedial procedures throughout food preparation and storage. It is also critical in product development since knowledge on a product's sensory qualities supports food companies and researchers in addressing customer demands and offering new and improved products [15]. Many researchers employ basic approaches such as descriptive analysis, consumer tests, and preference mapping to complete sensory quality analyses. Descriptive sensory analysis is based on the perceptions of a trained group of assessors who provide quantitative descriptions of all food product sensory qualities. Consumer testing determines whether consumers like, accept, or prefer one product over another [16]. Preference mapping describes the features led to consumer liking through the use of a visual representation that illustrates the relationship between descriptive sensory data and consumers' hedonic ranking [16].

The purpose of this study was to investigate the effect of varying concentrations of Moringa oleifera leaf and sardine powders on textural profile, cooking quality, and sensory evaluation of dried noodles.

2. MATERIALS AND METHODS

2.1 Samples Collection

Moringa leaves were collected from Frida home steady farms located in Morogoro region where as dried sardines , cooking oil, salt, wheat flour and baking powder (sodium carbonate) were collected from chief Kingalu market at Morogoro region, Tanzania

2.2 Sample Preparation

2.2.1 Preparation of moringa leaf powder

Moringa leaf powder was made according to Orisa and Udofia [18], Kumar [19] with minor changes. Moringa leaves were collected from the farm and sorted, with healthy leaves being chosen for further processing and damaged leaves being discarded. Selected leaves were washed with distilled water to remove all dirt and dust. The leaves were placed on perforated trays and widely spread for 20 minutes to drain excess water. After 20 minutes, trays were arranged on laboratory tables and dried for 4 days under shade until the moisture content reaches 7%. After drying, the leaves were ground into a fine powder with a high speed multifunctional crusher machine (Model 750A), then sieved through a stainless steel sieve with 500 µm. Then powder was packed in airtight zipped bag to avoid absorption of the surrounding moisture which may degrade its quality and nutrients for further processes.

Fig. 1. Moringa oleifera leaves

2.2.2 Preparation of sardine powder

Dried Sardine heads were removed, and the remaining parts were washed with portable water to remove sand and other foreign matter. Sardines were spread on oven trays after being washed, then placed on oven set at 60°C ready for the drying process. After 42 hours, dried samples with moisture content of 10% were removed from the trays and ground into fine powder using a high speed multifunctional crusher machine (model 750A), followed by sieving through a stainless steel sieve with 500 µm. Finally, the fine powder was sealed in airtight zipped bags and stored for further processing [20].

2.2.3 Sample formulation and composition

The samples were combined in proportions that meet the energy and micronutrient requirement of adolescents aged 14-19 years as suggested by WHO [21] using linear regression method. Six samples of noodles were formulated as indicated in the Table 1, therefore a total of seven samples were prepared including control.

Table 1. Composition of noodles incorporated with Moringa Leaf Powder and Sardine Powder (g/100g)

Ingredients	Formulation Name	Ratios
Wheat flour	WC	100:0
Wheat flour + moringa leaf powder	WM1	99.6:0.4
	WM2	99.2:0.8
	WM3	99:1
Wheat flour + sardine powder	WS1	95:5
	WS2	90:10
	WS3	85:15

Fig. 2. Sardines (Rastrineobola argentea)

Fig. 3. Dried noodle samples packed in zipped bags

2.2.4 Dried noodle preparation

The dried noodle preparation procedures were followed as described by Zula *et al.* [22], the obtained moringa leaf powder and wheat flour were mixed using the following blending proportions in percentage-: 100:0, 99.6:0.4, 99.2:0.8, and 99:1. Also, sardine powder and wheat flour were mixed in the following proportions: 95:5, 90:10, and 85:15, which were measured using BOECO Germany analytical balance (Boeckel + Co BBL31 21505716 XX43-0035) before processing. After measuring those proportions, the composite flour was mixed for five minutes in Amasadora Spiral Mixer Heavy Duty 3 Speed Flour Dough Mixer Machine (model number SC-B30), then 300mls of water, 3g of salt, 2% cooking oil and 5g of sodium carbonate (baking powder) were added and continuously mixed to ensure that the dough had adequate consistency. The prepared dough was then placed in a laboratory extruder machine (china pasta making machine model number IT-IPM60) for cold extrusion of desired shape noodles. Finally, extruded noodles were cut into similar sizes and arranged on trays before drying at room temperature for 48 hours (2 days), after which they were packed in zipped bags and stored at room temperature around 25°C for further analysis and sensory evaluation.

2.2.5 Texture analysis of noodles

The texture profile analysis was determined in accordance with Coello *et al.* [23], Xu *et al.* [24] with minor modifications. 20 g of noodles were cooked in 200 mL of water for 11 minutes using the kjeldahl apparatus. After 11 minutes, the cooked noodles were drained and set aside for 10 minutes to remove any remaining water. For the texture profile analysis, 1.5 mm thick and 30mm long noodles were placed on plates according to their blending ratios. A texture analyzer (CT3™ texture analyzer) was used, and one strand of noodle was placed on a machine and compressed with a stainless-steel cylindrical probe (1.0 mm in diameter and 43 mm in length), and hardness, cohesiveness, springiness, and adhesiveness were calculated. For each blending ratio, measurements were repeated for three times.

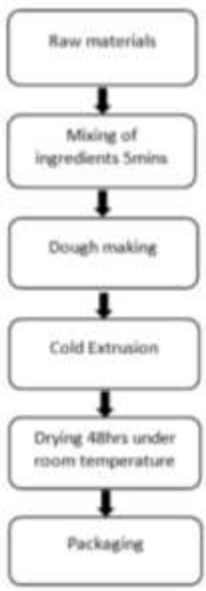

Fig. 4. A flow diagram showing noodle preparation
Source: Modified from Orisa and Udofia. [18]

2.3 Cooking Quality of Dried Noodles

2.3.1 Cooking loss

The amount of solid substance lost in cooking water is referred to as cooking loss. It was determined according to procedures explained by Kumar [19], Pakhare *et al.* [25]. During the determination, 10 g of noodle sample was measured using a BOECO Germany analytical balance (Boeckel + Co BBL31 21505716 XX43-0035). It was then transferred to a conical flask and 250 mL of distilled water was added. The conical flask with the sample was placed in the kjeldahl apparatus and cooked for 20 minutes. After 10 minutes, 25 mL of cooking water was collected in a petri dish and placed in a 105°C air oven until all water evaporated to dryness. The residue was measured and results were recorded. Analysis was done in triplicates for each blending ration and the following formula was used to calculate cooking loss.

$$\text{Cooking loss \%} = \frac{\text{weight of cooking water dried residue}}{\text{Weight of raw noodles}} \times 100 \quad (i)$$

2.3.2 Water absorption index

The water absorption index was calculated using the procedures described by Aydin and Gocmen [26], Shere *et al.* [27] with minor modifications. 10 g of noodle sample was measured and placed in a conical flask, then 250 mL of water was added. The sample was transferred to the kjeldahl apparatus and cooked for 10 minutes. The cooking water was drained, and a cooked noodle sample was weighed using BOECO Germany analytical balance (Boeckel + Co BBL31 21505716 XX43-0035). The analysis was conducted in triplicates and results was recorded. The following formula was used to calculate the water absorption index.

$$\text{Water Absorption Index \%} = \frac{\text{Weight of cooked noodle} - \text{weight of uncooked noodle}}{\text{Weight of uncooked noodle}} \times 100 \quad (ii)$$

2.3.3 Volume increase

The volume increase was determined using the procedures described by Kang *et al.* [28], Shere *et al.* [27] 150 mL of water was placed in a 1000 mL measuring cylinder, followed by 10 g of noodle sample, and the volume increase was immediately recorded for uncooked noodles. 10 g of noodles were cooked in a conical flask for 10 minutes using the Kjeldahl apparatus. After cooking, the cooking water was drained, and the noodle sample was poured into a 1000 mL measuring cylinder filled with 150 mL of water, and the volume increase was recorded. For each blending ratio analysis was done in triplicates and the following formula was used to calculate volume increase.

$$\text{Volume increase \%} = \frac{\text{volume of cooked noodle} - \text{volume of uncooked noodle}}{\text{Volume of uncooked noodle}} \times 100 \quad (iii)$$

2.4 Sensory Evaluation

2.4.1 Quantitative descriptive analysis

A quantitative descriptive analysis was carried out in the Department of Food Science and Agro-processing laboratory at Sokoine University of Agriculture (SUA), using 10 trained panelists, 5 males and 5 females, ranging in age from 21 to 25 years old, as described by Heymann *et al.* [29], Lawless and Heymann [30] with minor modifications. Panelists received two days of training in developing sensory descriptors and defining sensory attributes. They all agreed on four characteristics: color, aroma, saltiness and hardness. Aside from agreement on the definition of sensory attributes, panelists developed and agreed on an unstructured 5-line scale for rating the intensity of product sensory attributes, with the left side of the scale representing the lowest intensity of each attribute value (1) and the right side representing the highest intensity value (5). The samples were coded using 3-digit random numbers, and then they were served to each panelist at random. Panelist responses were obtained and used in both univariate and multivariate analysis.

2.4.2 Hedonic test

Hedonic test was conducted at Morogoro secondary in morogoro municipality by 61 untrained panelists aged 14 to 19 years using a 9 point hedonic scale where by 1= dislike extremely and 9=like extremely as described by Heymann and Lawless [16], Mongi *et al.* [15].samples were coded with 3-digit random numbers and served to panelists in random order with distilled water for rinsing. Panelists were asked to indicate their level of liking and dislike for the specified attributes of color, aroma, mouth feel, taste, and overall acceptability as shown on the sensory form by writing the numbers provided in the hedonic scale based on their preferences.

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

Attributes	Description	Reference	Scale ranges
Color	Characteristic of visual perception described through color categories	-Moringa leaf -sardine powder	1-not at all 5-extremely colourfull
Saltiness	The quality of being salty	1% Table salt (Nacl)	1- Not at all 5-extremely salty
Hardness	Characteristic of the product as perceived for the first teeth bite	Cooked Santa Lucia noodles	1-very hard 5-extreme soft
Aroma	Component of odour caused by a product identified by the sense of smell	-Moringa leaf powder -sardines	1-not at all 5-extreme smell

2.4.3 Cooking of noodles

Cooking procedures were followed with minor modifications as described by Zula *et al*. [22]. Noodle samples were cooked in boiling water for 9-11 minutes in a small stainless steel source pan. To keep the samples from sticking together, they were stirred with a wooden kitchen spoon. After cooking, the sample was strained and washed with cold running water then 2mls of cooking oil was added to a source pan, followed by noodles, and cooked for 2 minutes for sensory evaluation.

2.4.4 Statistical data analysis

Statistical data analysis were perfomed 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 Tukey'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 as well as partial least square regression (PLSR) was performed by unscrambler X software version 10.4 to check the relationship between quantitative descriptive data and consumer data.

3. RESULTS AND DISCUSSION

3.1 Textural Characteristics of Noodles

Textural characteristics are key attributes for noodle cooking qualities that are fundamental basis of final consumer acceptance. Table 3 presented the textural properties of cooked experimental noodles incorporated with moringa leaf and sardine powders.

3.2 Hardness

The force needed to compress or bite through a food sample is referred to as hardness. The results demonstrate that as the amount of moringa and sardine powder was increased, the hardness of the noodles diminished. All samples of noodles varied significantly in terms of hardness ($p<0.05$), as shown in Table 3. The maximum hardness result (64.7 g) came from the WC (control sample), indicating that the noodles' texture is stiffer. The hardness levels continuously drop as we move to WM1, WM2, and WM3, as seen in the table above. In WS1, WS2, and WS3, the inclusion of sardine powder considerably decreases the hardness. This reduction could be related to the use of sardine and moringa powders, which may soften the texture of the noodles because they contain less carbohydrate and gluten levels compared with wheat flour. Also, hardness is additionally affected by the matrix structural network of starch, additional proteins and other components that were present in the supplements (moringa leaf powder and sardine powder). Similar result was observed in research done by Coello *et al.* [23] on pasta products enriched with moringa sprout powder as nutritive dense foods with bioactive potential who observed decrease in hardiness as moringa sprout powder increases. Also, the study of Weng *et al.* [31] on preparation of white salted noodles using rice flour as the principal ingredient and the effects of transglutaminase on noodle qualities reported the decrease in hardness upon the use of gluten free flours.

Table 3. Textural properties of cooked noodles

Sample	Hardness(g)	Cohesiveness	Springiness(mm)	Adhesiveness(mJ)
WC	64.7 ± 2.5^{a}	0.8 ± 0.6^{g}	2.1 ± 0.2^{m}	0.3 ± 0.3^{r}
WM1	45.2 ± 1.9^{b}	0.7 ± 0.0^{gh}	1.9 ± 0.1^{m}	0.2 ± 0.1^{r}
WM2	26.8 ± 0.3^{c}	0.6 ± 0.1^{hi}	1.6 ± 0.1^{mn}	0.2 ± 0.1^{r}
WM3	20.3 ± 1.3^{d}	0.5 ± 0.0^{i}	1.5 ± 0.0^{mn}	0.1 ± 0.1^{r}
WS1	13.7 ± 1.5^{e}	0.6 ± 0.1^{ghi}	1.1 ± 0.3^{np}	0.2 ± 0.1^{r}
WS2	9.5 ± 0.8^{ef}	0.4 ± 0.1^{jk}	0.8 ± 0.6^{p}	0.2 ± 0.1^{r}
WS3	8.8 ± 1.6^{f}	0.4 ± 0.0^{k}	0.8 ± 0.1^{p}	0.1 ± 0.0^{r}

Values are expressed as mean± standard deviation. Mean values with different superscript letters along the column are significantly different at (p≤0.05).

WC (100% Wheat), WM1 (99.6%wheat: 0.4% Moringa leaf powder), WM2 (99.2%wheat:0.8% Moringa leaf powder), WM3 (99%wheat:1% Moringa leaf powder), WS1 (95%wheat:5% Sardine powder), WS2 (90%wheat:10% Sardine powder), WS3 (85%wheat:15% Sardine powder)

3.3 Cohesiveness

A significant difference in cohesiveness was observed among all noodle samples ($p < 0.05$).The control sample (WC) exhibited the highest cohesiveness value, indicating excellent structural integrity and a strong ability of the noodles to stick together. However, as the amount of moringa powder increased in WM1, WM2 and WM3 a slight decrease in cohesiveness was observed. This suggested that the addition of moringa may have influenced the binding properties of the noodles, resulting in a minor reduction in their ability to stick together. The observed decrease in noodle cohesiveness with the addition of moringa powder can be attributed to two potential mechanisms: changes in starch behavior and particle distribution. Noodles typically contain starch, which contributes to their texture and cohesiveness. Moringa powder may interact with the starch molecules, potentially interfering with their gelatinization process and leading to a less cohesive noodle texture. Furthermore, moringa powder consist of fine particle that can be unevenly distributed throughout the noodles so these particles disrupt the alignment and interaction of the noodle strands, thereby reducing their cohesiveness.

Additionally, the results presented in Table 3 showed the decrease of cohesiveness in WS1, WS2, and WS3 compared to control sample (WC). The observed decrease in cohesiveness in the experimental groups implies a potential negative impact of sardine powder on the structural integrity of noodles as the presence of sardine powder can disrupt the protein network and impair gluten formation by interfering with the proper bonding of gluten hence compromise the cohesive properties of noodles, making them more fragile and prone to breakage. These results abide with those of Coello *et al.* [23] on pasta products enriched with moringa sprout powder as nutritive dense foods with bioactive potential who observed decrease in cohesiveness as moringa sprout powder increases. Khatkar and Kaur [32] researched on the effect of protein incorporation on functional, thermal, textural and overall quality characteristics of instant noodles and observed the decrease of cohesiveness as well. According to the study of Ainsa *et al.* [33], there was a decrease in cohesiveness of noodles incorporated with different concentration of fish-by product.

3.4 Springiness

Springiness refers to the ability of the noodle to regain its original shape after deformation. Pasqualone *et al.* [34], postulate that springiness measures the extent of recovery that occurs when a compressive force is removed. Results demonstrate significant difference in springiness among all formulated noodle samples ($p<0.05$). The control sample (WC) had the highest springiness value which indicate good elasticity, and this could be attributed by the gluten protein content in wheat flour which was not substituted with sardine powder and moringa leaf powder. As the amount of moringa and sardine powder increases, the springiness decreases gradually in WM1, WM2, WM3, WS1, WS2 and WS3. This decrease in springiness could be due to the alteration of the gluten network in the noodles caused by the supplement materials (moringa leaf and sardine powders) because gluten is the type of protein responsible for the elasticity of products which contain wheat flour, including noodles. Also, the increase in concentration of supplements reduces the degree of elasticity in noodles because the gluten found in wheat flour decreases. Furthermore, the inclusion of supplements containing dietary fibre might be the reason as they tend to affect the integrity of protein-starch network hence resulting in lower values of springiness after cooking [35]. This results abide with Pasqualone *et al.* [34], on functional, textural and sensory properties of dry pasta supplemented with lyophilized tomato matrix or with durum wheat bran extracts produced by supercritical carbon dioxide or ultrasound and shows that there was a decrease in springiness.

3.5 Adhesiveness

Adhesiveness refers to the tendency of a food to stick to surfaces, such as teeth or utensils. Results show that there was no significant difference among all noodle sample ($p>0.05$).The adhesiveness values remain relatively constant across all samples, indicating that the addition of moringa or sardine powder does not significantly affect the stickiness of the noodles. This could be attributed by the addition of moringa leaf powder and sardine powder which may not possess strong binding properties compared to the control ingredients hence interfere with the gluten content of wheat flour and cause a slight decrease in adhesiveness of noodles. Results abide with the study done by Nochai and Pongjanta [36] who studied on the physicochemical properties of dried noodle with tomato lycopene supplement and observed no significant difference on adhesiveness. But the results go against with the study done by of Ainsa *et al.* [33] on quality parameters and technological properties of pasta enriched with a fish by-product who observed the increase of adhesiveness in pasta compared to control sample.

3.6 Cooking Loss

Cooking loss is the weight of solids lost in boiling water. It is one of the most commonly used measures to assess the overall quality of noodles by reflecting the degree of noodle damage and the ability of noodles to maintain their strength during cooking time [37].

Cooking loss increases with the amount of moringa leaf powder used, as well as in noodles mixed with sardine powder when compared to the control sample. The results demonstrate that noodles complemented with moringa leaf powder have a cooking loss ranging from 16 to 18.9%, whereas noodles infused with sardine powder have a cooking loss ranging from 20 to 31%. This could be related to the weakening of the protein starch matrix due to the lower amount of wheat gluten protein when moringa leaf powder and sardine powder were added to wheat flour and the cooking time. This outcome is similar to Simonato *et al.* [2], who also discovered that adding moringa leaf powder to wheat flour increased cooking loss. Furthermore, the findings are consistent with a study conducted by Jyoti *et al.* [38], which found that incorporating small fish powder into wheat flour results in increased cooking loss because fish powder contains a non-gluten protein that reduces the binding capacity of gluten found in wheat flour, resulting in a large amount of solid soluble components leached into water during cooking.

According to the findings, there was a significant difference in cooking loss between all formulated samples ($p<0.05$) based on a study conducted by Getachew and Admassu [39], Sholichah *et al.* [40], which indicated that noodles of good quality should have a cooking loss of less than 12%; thus, in this research, noodles developed from wheat flour alone (control) have good cooking quality compared to other designed samples incorporated with moringa leaf and sardine powder.

3.7 Water Absorption

Water absorption is the amount of water absorbed by dry noodles during cooking and retain it after draining. It is also a parameter used to assess the cooking quality of noodles. From the findings it appears that there was a significant decrease in water absorption as the amount of moringa leaf and sardine powder increase. Noodles incorporated with moringa leaf powder its water absorption decreases from 282.8 to 251.7% and those incorporated with sardine powder decreases from 294.7 to 248.2% compared to control sample. This could be attributed by substitution of wheat flour with sardine and moringa leaf powder in noodle samples which reduces noodle water absorption by competing with the starch for water during noodle development. Also, moringa leaf powder contain fibres which may fight for water absorption with wheat flour proteins thus lowering the dough's overall water uptake ability which results in reduction in water absorption of noodles [41] .These findings abide with the study done by Desai *et al.* [42] who researched on the effect of semolina replacement with protein powder from fish (Pseudophycisbachus) on the physicochemical characteristics of pasta and found that during pasta formation, fish powder is competing with the starch which reduce starch swelling and consequently water absorption of pasta. Dziki [43] revealed that the addition of moringa leaf powder in noodle could potentially interfere with gluten formation, affecting the dough's ability to absorb water efficiently compared to control noodle sample.

3.8 Volume Increase

Volume increase is among of the parameters used in assessing the quality of noodles which provides insights into texture, mouthfeel, cooking performance, consumer preference, and product consistency. The findings shows that there was a significant difference in volume increase between noodle sample ($p<0.05$). Volume increase of control noodle sample was 694.8% while those incorporated with moringa leaf powder decreased from 433.5% to 293.7% and those incorporated with sardine powder the decrease ranged from 256.3% to 205.4% this could be attributed from the significantly high cooking loss that occurred in samples incorporated with moringa leaf powder and sardine powder as it shown on the Table 4 but also the the decrease of volume increase during boiling of the noodles could be caused by starch gelatinization and protein hydration related to the size of the starch [28]. Furthermore, Moringa leaf powder has the ability to absorb moisture, which can lead to a decrease in the volume increase of noodles during the cooking process. Also as the powder absorbs moisture from the dough, it can affect the hydration level and reduce the expansion of the noodles. Apart from the above reasons, also the presence of compounds such as protein and fibres in sardine powder and moringa leaf powder can affect the gluten network formation and starch gelatinization process, leading to a more compact and less porous structure in the noodles which results to decrease in volume expansion.

Table 4. Cooking quality of noodles incoporated with moringa and sardines powders

Sample	Cooking Loss%	Volume Increase%	Water Absorption%
WC	7.6 ± 0.4^{a}	694.8 ± 5.9^{f}	318.3 ± 3.3^{e}
WM1	16.0 ± 0.6^{b}	433.5 ± 1.3^{g}	282.8 ± 1.2^{p}
WM2	17.5 ± 1.4^{b}	371.1 ± 3.9^{h}	273.1 ± 1.7^{p}
WM3	18.9 ± 1.2^{bc}	293.7 ± 6.7^{i}	251.7 ± 0.2^{mn}
WS1	20.7 ± 0.4^{c}	256.3 ± 29.9^{j}	294.7 ± 4.7^{l}
WS2	25.2 ± 0.8^{d}	226.5 ± 5.6^{k}	259.4 ± 1.0^{n}
WS3	31.4 ± 1.9^{e}	205.4 ± 18.8^{k}	248.2 ± 7.5^{m}

Values are expressed as mean± standard deviation. Mean values with different superscript letters along the column are significantly different at (p≤0.05).
WC (100% Wheat), WM1 (99.6%wheat: 0.4% Moringa leaf powder), WM2 (99.2%wheat:0.8% Moringa leaf powder), WM3 (99%wheat:1% Moringa leaf powder), WS1 (95%wheat:5% Sardine powder), WS2 (90%wheat:10% Sardine powder), WS3 (85%wheat:15% Sardine powder)

Table 5. Consumer acceptability of noodles incoporated with moringa and sardine powders

Sample	Color	Aroma	Mouth Feel	Taste	Acceptability
WC	6.4 ± 1.6^{d}	6.1 ± 2.1^{h}	5.8 ± 2.2^{l}	6.1 ± 2.6^{p}	6.0 ± 2.7^{tu}
WM1	6.2 ± 2.3^{c}	6.4 ± 2^{h}	5.7 ± 2.2^{kl}	6.2 ± 2.3^{p}	6.5 ± 2.2^{v}
WM2	5.7 ± 2.6^{bc}	6.2 ± 2.1^{h}	5.6 ± 2.3^{kl}	6.2 ± 2.3^{p}	6.2 ± 2.3^{tu}
WM3	4.8 ± 2.2^{ab}	5.4 ± 2.3^{gh}	5.4 ± 2.5^{kl}	5.7 ± 2.8^{op}	5.6 ± 2.3^{stu}
WS1	5.9 ± 2.2^{bc}	4.5 ± 2.8^{fg}	4.7 ± 2.7^{k}	4.5 ± 2.9^{mn}	5.4 ± 2.6^{st}
WS2	5.1 ± 2.7^{bc}	3.9 ± 2.6^{ef}	4.5 ± 2.4^{k}	3.9 ± 2.9^{m}	4.4 ± 2.7^{r}
WS3	3.6 ± 2.6^{a}	2.9 ± 2.2^{e}	4.3 ± 2.7^{j}	3.5 ± 2.7^{m}	3.0 ± 2.4^{r}

Values are expressed as mean± standard deviation (n=60). Mean values with different superscript letters along the column are significantly different at (p≤0.05).
WC (100% Wheat), WM1(99.6%wheat:0.4% Moringa leaf powder), WM2 (99.2%wheat:0.8% Moringa leaf powder), WM3 (99%wheat:1% Moringa leaf powder), WS1 (95%wheat:5% Sardine powder), WS2 (90%wheat:10% Sardine powder), WS3 (85%wheat:15% Sardine powder)

3.9 Color

Color is the most important element of any food's appearance, and it plays a fundamental role in its appearance and consumer acceptability. Although consumers' color preferences vary, a product's color significantly impacts its sales [44]. It is essential to examine color attributes in product development because color differences between the new product and the old one might lead to product acceptance or rejection because most consumers search for similarities between the new product and the one they have experience with.

Except for WM2, WS1 and WS2, there was a significant difference in color liking ($p<0.05$) across all samples. The control sample was slightly preferred by the panelists, with a mean score of 6.4, followed by noodle enriched with moringa leaf powder. The data demonstrates that as moringa leaf powder and sardine powder increased, the degree of color liking falls. This negative association may be linked to the green color of moringa leaf powder, which increases with concentration and hence affects customer acceptance. Also, because of the wood brown color of the sardine powder, the panelists disliked the color of the noodles mixed with 150g (WS3) sardine powder. This results support the study done by Prayitno *et al.* [45], revealed that, the higher the concentration of Moringa oleifera leaf flour used in the dough, the less attractive the color of the noodles will be. Zungu *et al.* [46], found that food products supplemented with moringa leaf powder were generally acceptable but acceptability decreased drastically as moringa leaf powder was increased to higher concentrations. Also study of Govender and Siwela [47] revealed that, there was a significant decrease in color acceptability as moringa leaf powder increases in brown bread. Also acceptability of noodles decreased upon increase of sardine powder which is similar to the result of the study done on pizza which found acceptability in color of pizza decreases as dried cap fish powder increases [48].

3.10 Aroma

Aroma refers to an odor, sensed through the nose and retronasal olfaction, i.e. through the back of the mouth where the nasal and mouth cavities are interlinked. It has a good contribution in product acceptability. Moringa oleifera leaves contain compounds that are easy to evaporate, so that when added to the noodle mixture it will evaporate and can be felt by panelist. Result shows that there was a significant difference in aroma between samples $p<0.05$ which means aroma of noodle samples were liked differently. The aroma of WM1, WM2 and WC was slightly liked by the panelist compared to other samples by having the mean score 6.4, 6.2 and 6.1 respectively. However the degree of aroma liking by panelist decreases as the concentration of moringa leaf powder increases as it shown in the Table 5. Noodles made by 10 g of moringa leaf powder (WM3) scores the mean value of 5.4 which fall in "neither like nor dislike "category. This decrease could be attributed by the leafy and herbal aroma of moringa leaf powder which affect consumer acceptability. These results abide with the study done by Prayitno *et al.* [45] on wet noodles added with different concentration of moringa leaf powder and shows that, in the treatment with the addition of 5% moringa oleifera leaf flour by hedonic test, it obtained a higher value of mean score along with the increase in the concentration of moringa oleifera leaf flour giving the panelists' preference for aroma decreased as the increase in concentration makes the noodle product have a sharp aroma like herbal medicine. Furthermore aroma of noodles incorporated with sardine was not liked by most of the panelists and this could be caused by the fishy aroma of sardine which negatively affect consumers liking. The aroma increases as the concentration of sardine powder increases which in turn affect the overall acceptance of the products. The aroma of all noodle samples with sardine powder was disliked by panelists but the degree of disliking increased as the concentration of sardine powder increase WS1 (5%)>WS2 (10%)>WS3 (15%) because the fishy aroma which naturally present increases with concentration. These results abide with the study of Goes *et al.* [49], who obtained the successful overall liking with replacement of 20g/100g of wheat flour by tilapia flour however 30g/100g decreased overall liking.

3.11 Mouth Feel

There were statistically significant difference in mouthfeel acceptance between samples ($p<0.05$). When compared to other samples substituted with moringa leaf and sardine powder, control noodles received the highest mean score of 5.8. This could be related to the high concentration of gluten protein in wheat flour, which resulted in elastic dough during preparation, resulting in noodles with excellent structure and mouthfeel. The mouthfeel acceptance of noodles samples containing

0.04% moringa leaf powder differs significantly ($p<0.05$) from samples containing 0.08% and 1% moringa leaf powder. This result could be due to diluting the gluten component found in wheat flour, which affects the texture (mouthfeel) of noodles and thus decreases consumer acceptance as the concentration increases. Also, as the concentration of sardine powder in noodle samples increase, acceptance decreases when compared to the control samples. As a result, increasing the proportion of sardine flour in wheat flour for noodle development reduces the amount of gluten protein in wheat flour, affecting texture and decreasing customer preference compared to the control sample. The findings are consistent with the findings of Kamble *et al.* [1], who discovered that the texture of the control pasta was preferred due to the presence of gluten in the flour, which has an influence on noodle texture improvement.

3.12 Taste

Taste is an attribute that is felt when something is placed on the tongue, and it is a major influencing factor in a person's choice of a particular food item. Taste preferences differed significantly amongst noodle samples ($p<0.05$). According to the findings, WC, WM1 and WM2 were slightly preferred by consumers in terms of taste, with a mean score of 6.2, but the sample containing 10 g of moringa leaf powder was liked differently, with a mean score of 5.7. The bitter taste of moringa leaf powder, which tends to be recognized as the concentration of moringa increases, might be attributed to the decrease in consumer preference. Prayitno *et al.* [45] demonstrated that increasing the concentration of moringa oleifera flour has an aftertaste effect on noodle products. Noodles incorporated with sardine powder WS1, WS2 and WS3 were not liked by panelists and the means scores decreased as the sardine powder increases. Decrease in taste acceptance could be attributed to the fishy taste present in sardines. This results abide with the findings of Sirichokworrakit [50], who studied the physical, textural and sensory properties of noodles supplemented with tilapia bone flour and found that the acceptability decreases as the concentration of tilapia bone flour increases.

3.13 Overall Acceptability

It was discovered that noodle samples with a high percentage of moringa leaf powder had low scores, which could be attributed to the green color and bitter taste of the leaves, which must have masked the normal color and taste of the noodles [18], however, noodles produced from a 0.04% replacement with a high percentage of wheat flour scored high in aroma and there was no significant difference in taste with the control sample, so it was accepted by panelists. Also, noodles with sardine powder score poorly, possibly due to the fishy odor and taste of sardine, which has a negative impact on consumer acceptance of the product. The concentration of 0.04% moringa leaf powder can be used in substitution of wheat flour since they were the most accepted by customers, followed by noodle samples using 0.08% moringa leaf powder, which shows no significant difference in acceptability ($p>0.05$) with noodles containing 100% wheat flour.

3.14 Quantitative Descriptive Analysis Results

The QDA sensory analysis provided valuable insights into the sensory attributes of the dried noodles with and without the addition of moringa leaf powder and sardine powder. The evaluation focused on color, aroma, saltiness and hardness of the noodles. The results revealed some notable differences among the samples.

Table 6. Quantitative descriptive analysis results of noodle samples

Sample	Color	Aroma	Saltiness	Hardness
WC	$2.1±1.1^{a}$	$2.4±1.2^{d}$	$2.5±1.5^{h}$	$3.6±1.0^{k}$
WM1	$3.1±1.0^{ab}$	$2.6±1.2^{de}$	$2.7±1.5^{h}$	$3.3±0.7^{k}$
WM2	$3.2±0.6^{ab}$	$2.6±1.3^{de}$	$2.5±1.4^{h}$	$3.1±1.1^{k}$
WM3	$3.4±1.3^{ab}$	$2.8±0.9^{de}$	$2.0±0.0^{h}$	$3.3±0.5^{k}$
WS1	$2.4±1.4^{abc}$	$3.4±0.7^{efg}$	$2.3±0.7^{h}$	$3.5±1.0^{k}$
WS2	$3.0±1.3^{bc}$	$3.8±0.8^{fg}$	$2.2±1.1^{h}$	$3.1±1.0^{k}$
WS3	$4.3±0.9^{c}$	$4.3±0.7^{g}$	$2.1±1.3^{h}$	$3.0±1.1^{k}$

Values are expressed as mean± standard deviation (n= 10). Mean values with different superscript letters along the column are significantly different at p≤0.05

WC (100% Wheat), WM1(99.6%wheat:0.4% Moringa leaf powder), WM2 (99.2%wheat:0.8% Moringa leaf powder), WM3 (99%wheat:1% Moringa leaf powder), WS1 (95%wheat:5% Sardine powder), WS2 (90%wheat:10% Sardine powder), WS3 (85%wheat:15% Sardine powder)

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Regarding color, there was a significant difference in color intensity between control sample (WC) and samples with sardine powder (WS1, WS2, WS3) as well as samples with moringa leaf (WM1, WM2, WM3) $p<0.05$. Also, samples made with moringa leaf powder showed no significant difference in color intensity among themselves $p>0.05$ as it is shown in Table 6 where by the use of small concentration of moringa leaf powder might be the reason. As the concentration of supplements increases also the mean color intensity increases from the control sample. Samples made with 15% of sardine powder possess higher color intensity. This might be due to higher concentration of sardine powder used.

Results on Table 6 shows that there was a significant difference in aroma intensity between control sample and the supplemented noodles with moringa leaf and sardine powders $p<0.05$. The increase in aroma intensity of the noodles as the concentration increase from the control was influenced by the addition of both moringa leaf powder and sardine powder. Samples with 10% and 15% of sardine powder were higher in aroma intensity.

In terms of saltiness, the quantitative descriptive analysis did not reveal significant differences between the control noodles (WC) and those with added ingredients (moringa leaf and sardine powders) $p>0.05$. The intensity of saltiness remained relatively consistent across all the samples.

On the aspect of hardness, results shows that there was no significant difference in hardiness intensity between control sample and samples incorporated with moringa and sardine powders $p>0.05$. All the noodles, including the control and those with added ingredients, displayed similar in hardness intensity. This suggests that the incorporation of moringa leaf powder and sardine powder did not significantly affect the texture or firmness of the noodles.

3.15 PCA Bi-plot

The bi-plot of principle component analysis (Fig. 5) shows that Dim1 explains 37.1% of the variation while Dim2 accounts for 31.2% of the variation. Noodles with 15% of sardine powder (WS3) were closely associated with aroma and color attributes as shown in the diagram followed by noodles incorporated with 10% of sardine powder (WS2). Noodles with 0.8% of moringa leaf powder (WM2) were associated with hardness, saltiness, color and aroma attributes as the ellipse representing it is located at the centre. The control sample (WC) of noodles show a slight association with hardiness but no association with color, aroma and saltiness.

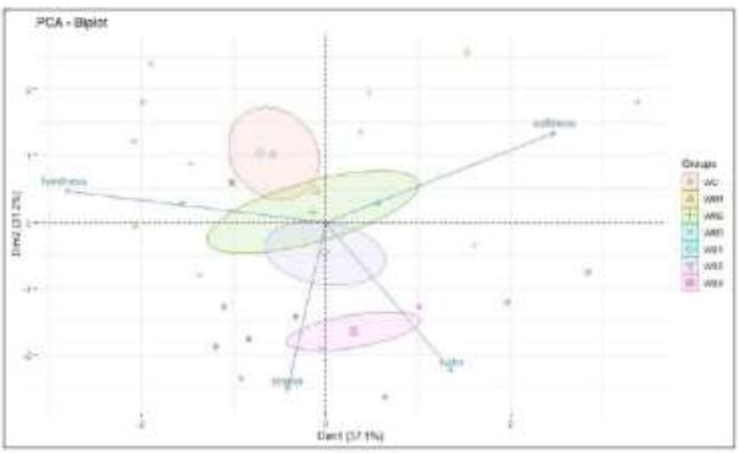

Fig. 5. Bi- plot of PCA showing association between attributes and sample

3.16 Relationship between Quantitative Data and Hedonic Liking (Consumer Data) by Partial Least Square Regression (PLSR)

The score plot (Fig. 6) and correlation loading plot (Fig. 7) illustrates the results of a partial least squares regression with descriptive data as X-variables and consumer like ratings as Y-variables. The first factor components explained 35% of the overall variation (X-35%, Y-11%), while the second factor components explained 28% of the total variation (X-28%, Y-2%). Figure 3 illustrates that many consumers shift toward the light of the horizontal X-axis, which is the direction of noodle liking, where noodles with 100% wheat flour and others with a little amount of sardine and moringa leaf powders are prominent. In addition from Fig. 6, the correlation loading plot (Fig. 7) depicts the effect of each attribute on noodle liking. Hardness, color #1, aroma #1, mouthfeel, taste, and saltiness all contributed to sample acceptance. Although the fact that color #2 and aroma #2 had a detrimental impact on sample acceptability. According to the data, the important attributes for consumer acceptability of noodles were color #1, aroma #1, and taste. This study supports the findings of Mongi *et al.* [15], Mongi and Gomezulu [51] who found that the product appearance, color, texture, and flavor are good indicators of intrinsic good quality and have a significant impact on customer acceptance and consumption.

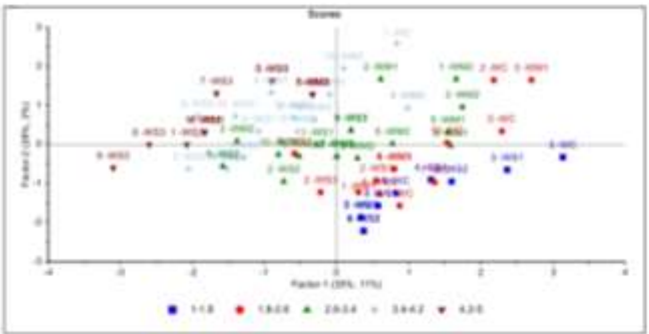

Fig. 6. Score plot from a partial least squares regression of noodles incorporated with sardine and moringa leaf powders samples with descriptive data as X variables and hedonic rating as Y variables

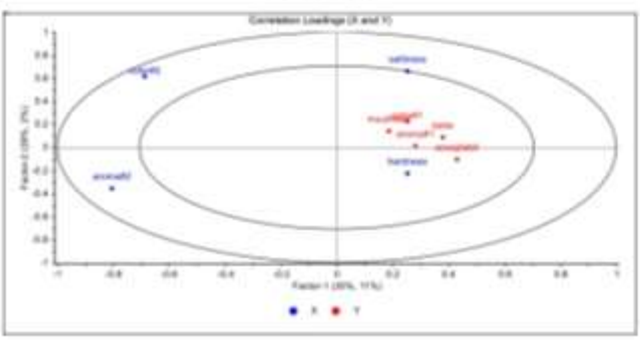

Fig. 7. Correlation loadings from a partial least squares regression of noodles incorporated with sardine and moringa leaf powders samples with descriptive data as X variables and hedonic rating as Y variables

4. CONCLUSION

This study revealed that, the incorporation of sardine and moringa leaf powders in noodles led to significant changes in textural properties, cooking quality, and sensory attributes of noodles. As the concentration of these ingredients increased resulted in softer noodles with reduced water absorption capacity and increased cooking losses. Sensory evaluations indicated that higher concentrations of moringa leaf powder and sardine powder resulted in decreased acceptability scores, particularly in terms of color, aroma and taste due to the bitter flavor and medicinal leaf smell imparted by moringa leaf powder as well as the fishy-smell of sardine powder. The formulation WM1 (99.6% wheat: 0.4% Moringa leaf powder) was the most accepted sample by panelist so that ratio is recommended to be used to improve the nutritional qualities of noodles as well as sensory properties of noodles. Additionally sardines formulation performed poor on textural, cooking quality and on sensory evaluation due to the high concentration used. So, in general the use of these ingredients is good for improving nutritional content of noodles but the concentration ratios used should be minimal in order to improve the sensorial properties of the product as well as increasing nutritional content.

ETHICAL CONSIDERATION

An ethical concern addressed in this research pertained to obtaining proper permissions for data collection. Prior to interviewing students at Morogoro Secondary school, the necessary research permits were obtained from the Vice Chancellor of Sokoine University of Agriculture and the Morogoro Regional Commissioner, in accordance with established protocols. Additionally, the Municipal Director's approval was secured, ensuring that the study adhered to ethical guidelines and respected the rights, privacy, and well-being of the participants. Confidentiality and informed consent were maintained throughout the research process, reflecting our commitment to upholding ethical standards and conducting a responsible study.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDICES

Appendix 1: Hedonic test

Hedonic test sensory evaluation form

Name of panelist...
Age.....................................**Sex**........
Paper number...
Date...................**Time**.................................

You are provided with seven (7) dried noodle samples, please evaluate each coded sample provided and indicate how much you like or dislike each attribute of the sample by putting the most appropriate number (1-9) in the column against each attribute (Table 1) by using hedonic scale provided below

Hedonic scale

1 2 3 4 5 6 7 8 9

KEY: 1- Dislike extremely, 2-Dislike very much, 3-Dislike moderately, 4-Dislike slightly, 5-Neither like nor dislike, 6-Like slightly, 7-Like moderately, 8-Like very much, 9-Like extremely.

Indicate your degree of liking in the Table 1 below:

Table 1. Hedonic test

	Sample code						
Attribute	345	290	425	135	820	721	515
Color							
Aroma							
mouthfeel							
Taste							
Overall acceptability							

Other recommendations
....
....

Thank you.

Appendix 2: Quantitative Descriptive Analysis

Quantitative descriptive sensory evaluation form

Panelist name...
Sex.. Age............................... Time..........

You are provided with seven coded samples of dried noodles, please kindly evaluate the samples and indicate the intensity of each attribute as provided in the Table 2 below using the line scale provided.

color

Not at all 1 2 3 4 5 extremely colorfully

Aroma

Not at all 1 2 3 4 5 extremely smell

Saltiness

Not at all 1 2 3 4 5 extreme salty

Hardness

Very hard 1 2 3 4 5 extreme soft

Table 2. Quantitative descriptive test

	Sample code						
Attribute	135	721	345	820	515	290	425
color							
aroma							
saltiness							
hardness							

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/104595

CHAPTER FOUR

4.0 GENERAL DISCUSSION

4.1 Nutritional Composition of Noodles

This study aimed to determine the effect of *Moringa oleifera* leaf and sardine powders on the nutritional composition of noodles, including crude protein, carbohydrate, crude fibre, crude fat, ash, energy, as well as minerals such as calcium, magnesium, iron and zinc. The results show that incorporating sardine and moringa leaf powders into wheat noodles affects their nutritional composition, particularly protein and mineral content. The crude protein content increased with increasing levels of sardine and moringa leaf powders, with the highest value observed in a sample containing 15% sardine powder (WS3), indicating that sardine and moringa leaf powders are good protein sources. The crude fat content also increased with increasing levels of sardine powder, which is rich in fat. The crude fibre content decreased with increasing levels of sardine and moringa leaf powders, which might be due to the dilution effect of the added powders.

Additionally, ash content increased with increasing levels of sardine and moringa leaf powders, as sardines are rich in minerals such as calcium and iron. On the other hand, the carbohydrate content decreased with increasing levels of sardine and moringa leaf powders, likely due to the dilution effect of the added powders. The inclusion of moringa and sardine powders did not significantly increase in energy compared to the control sample. These results are in line with the study conducted by Zula *et al*. (2021) on the proximate composition, antinutritional content, microbial load, and sensory acceptability of noodles formulated from moringa (*Moringa oleifera*) leaf powder and wheat flour blend.

Furthermore, incorporating sardine and moringa leaf powders into wheat noodles affects their mineral content. Results show that calcium (Ca), iron (Fe), magnesium (Mg), and zinc (Zn) content increased with increasing levels of sardine and moringa leaf powders, with the highest values observed in the sample with 15% of sardine (WS3) and the sample with 1% of moringa leaf powder (WM3), respectively. Such an increase can be due to the large amount of minerals in sardine and moringa leaf powders, especially iron, calcium, zinc, and magnesium. These results are similar to a study by Moxness Reksten *et al*. (2020); Rao and Annadana, (2017), who found an increase in nutritional content in the use of marine fish in staple food crops.

The increase in mineral content is particularly important as these minerals are essential for various physiological functions in the body. Additionally, iron is essential for preventing anaemia and adolescent girls who lose a lot of iron during their menstruation period.

4.2 Textural Properties of Noodles

Incorporating texture analysis in this study was crucial as it sheds light on the physical attributes of the noodles. Texture greatly influences sensory perception, hence understanding its impact is necessary. Results demonstrate how the incorporation of moringa and sardine powders affects not just texture but potentially sensory attributes as well, which needs further investigation on these effects.

Generally, results showed that the incorporation of moringa leaf and sardine powders affects the textural properties of noodles. As the percentage of moringa leaf powder or sardine powder increased, the hardness of the noodles decreased, which is consistent with other studies showing that the addition of non-wheat ingredients to noodles can result in softer textures (Kang *et al*., 2017; Herawati *et al*., 2017)**.** The cohesiveness of the noodles also decreased as the percentage of moringa leaf powder or sardine powder increased, likely due to the lack of gluten-forming properties of these ingredients (Zhang *et al*., 2010). The springiness of the noodles decreased along the same trend as the hardness, while the adhesiveness of the noodles remained relatively constant. The results are similar to those of other studies investigating the textural properties of noodles made with non-wheat ingredients. For example, a study on noodles made with sweet potato composite flour found that as the percentage of sweet potato flour increased, the hardness and cohesiveness of the noodles decreased (Kang *et al*., 2017).

4.3 Cooking Quality of Noodles

The study investigated the cooking quality of noodles with moringa and sardine powders. The results showed that the cooking loss, volume increase, and water absorption of the noodles increased with the addition of moringa and sardines powders. The trend was significant with higher concentrations of moringa leaf powder or sardine powder, resulting in greater cooking loss and lower volume and water absorption. This is similar to a previous study that investigated the effect of *Moringa oleifera* leaf powder on the physical quality, nutritional composition, and consumer acceptability of white and brown bread. It found that adding *Moringa oleifera* leaf powder significantly increased cooking loss and decreased loaf volume (Govender and Siwela, 2020). Also, similar results were found in line with the results of Offiah et al. (2019), which found an increase in cooking loss, a decrease in volume, and water absorption of noodles incorporated with fish.

Generally, for consumers, understanding the impact of these supplements on cooking loss is crucial, as it directly influences the yield and texture of the final product they consume. Additionally, the observed decrease in volume increase and water absorption suggests potential alterations in the sensory attributes of the noodles, which consumers often associate with quality. For processors, these findings provide valuable insights into the formulation of noodle products enriched with moringa and sardine powders. By recognizing the effect of supplementation ratios on cooking loss and other parameters, processors can fine-tune their production processes to optimize product quality and ensure consistency. Furthermore, this understanding enables processors to effectively communicate the benefits of these enriched noodles to consumers, emphasizing aspects such as nutritional value and potential health benefits associated with the incorporation of moringa and sardine powders.

4.4 Sensory properties of composite Noodles

4.4.1 Consumer acceptability

The consumer acceptability evaluation of noodles incorporated with moringa and sardine powders revealed significant variations in the products' sensory attributes and overall acceptability. Notably, the control sample (100% wheat- WC) demonstrated the highest scores in colour, aroma, mouthfeel, taste and overall acceptability, indicating a preference for traditional wheat-based noodles. As the incorporation of moringa and sardine powders increased in the samples, a general trend of decreasing acceptability was observed, suggesting that higher concentrations of these ingredients negatively impacted the sensory attributes. Specifically, samples WM3, WS1, WS2, and WS3, which contained higher proportions of moringa and sardine powders, exhibited the lowest scores in colour, aroma, mouthfeel, taste, and overall acceptability. These findings indicate that the sensory profile of noodles is adversely affected as the percentage of these unconventional ingredients increases, which is essential to consider when developing products and anticipating consumer acceptance. Nonetheless, the study emphasizes the potential for enhancing the nutritional value of noodles by incorporating moringa and sardine powders, and further research and product optimization may be necessary to find a balance between sensory appeal and nutritional enrichment to meet consumer preferences and dietary needs. These results abide with the study done by Pathak and Kochhar, (2018), who reported that the inclusion of moringa leaf powder in snacks altered the sensory characteristics, including colour and aroma, as well as general acceptability as the concentration increased.

4.4.2 Quantitative Descriptive Analysis of Noodles

The Quantitative Descriptive Analysis (QDA) results provide valuable insights into the sensory attributes of the noodles, both with and without the inclusion of moringa leaf and sardine powders. Notable differences were observed across the samples, particularly in colour and aroma. Significantly higher colour intensity was observed in samples with sardine powder, with the intensity increasing as the concentration of sardine powder rose. Meanwhile, adding moringa leaf powder, even at varying concentrations, did not significantly alter colour intensity. Aroma intensity significantly increased by incorporating both moringa and sardine powders, especially in samples with higher sardine powder content. However, saltiness remained consistent across all samples, indicating that the supplements did not impact saltiness perception. Lastly, there were no significant differences in hardness between the control and supplemented noodles, suggesting that the texture remained unchanged despite the additions. These results emphasize the potential for adjusting colour and aroma attributes through the judicious use of these additives, while saltiness and hardness are less affected by their incorporation. Results are similar to the study of Kamble et al. (2018) on the effect of incorporating drumstick leaf powder and defatted soybean flour on the texture, colour and organoleptic evaluation of instant noodles.

4.4.3 Preference Mapping

PCA bi-plot analysis reveals how the various concentrations of sardine and moringa powders interact with the sensory properties of the noodles, emphasizing the importance of concentration in influencing aroma and colour, with sardine powder playing a particularly important role. Dimension 1 (Dim1) explains 37.1% of the overall variation, while Dimension 2 (Dim2) accounts for 31.2%.

The close relationship between noodles containing 15% sardine powder (WS3) and specific sensory characteristics, notably aroma and colour, is an important finding from this study, suggesting that higher sardine powder concentrations have a significant impact on these two characteristics, potentially resulting in a stronger fishy aroma and a distinctive colour. The link between aroma and colour also appears to be present in noodles containing 10% sardine powder (WS2), supporting the idea that the amount of sardine powder significantly affects these sensory qualities. On the other hand, noodles containing 0.8% moringa leaf powder (WM2) are positioned in the middle of the bi-plot, indicating a balanced and neutral sensory profile. The fact that the ellipse for WM2 is in the centre, showing weak associations with any particular sensory characteristics, further suggests that a moderate amount of moringa leaf powder has a less significant effect on individual attributes. However, the lack of associations with other attributes implies that WC remains unchanged mainly in colour, aroma, and saltiness compared to the supplemented noodles. These results abide with the study of Jadhav and Anal, (2018) on biochemical, microbial and sensory properties of Nile tilapia (Oreochromis niloticus) treated with moringa (Moringa oleifera) leaves powder.

4.4.4 Partial Least Square Regression (PLSR)

The application of Partial Least Squares Regression (PLSR) to explore the relationship between quantitative data and consumer hedonic liking ratings has yielded significant insights, as illustrated in Figures 6 and 7 The first factor component, accounting for 35% of the overall variation in the data, primarily directed consumer preferences toward the horizontal X-axis, corresponding to noodle liking. Notably, noodles made with 100% wheat flour and those with minimal amounts of sardine and moringa leaf powders stood out as prominent choices in terms of consumer liking. This finding underscores the importance of traditional ingredients and the preference for noodles that stay close to the baseline formulation.

The correlation loading plot explores the attributes that affect noodle liking. Hardness, colour #1, aroma #1, mouthfeel, taste, and saltiness were identified as contributing to consumer acceptability.

These findings suggest that noodles that are perceived to have the right texture (hardness), attractive colour (colour #1), and pleasant aroma (aroma #1) are more likely to be well-liked by consumers. Mouthfeel, taste, and saltiness are important in determining consumer preferences. Interestingly, colour #2 and aroma #2 seem to have a negative impact on sample acceptability, indicating that certain deviations in colour and aroma profiles may diversely affect consumer liking.

The results of this study align with previous research conducted by Mongi *et al*. (2013) and Mongi and Gomezulu, (2022), who emphasized the importance of product appearance, colour, texture, and flavour in determining intrinsic quality and their significant influence on customer acceptance and consumption. This reinforces the idea that consumers are influenced by sensory attributes such as colour, aroma, and taste when forming their opinions. In the context of noodle products, these findings highlight the importance of optimizing these sensory attributes to ensure consumer satisfaction and acceptance. By focusing on attributes that have the greatest impact on liking, product developers can effectively tailor their formulations to meet consumer preferences.

4.5 Mechanism behind the changes occurred through incorporation of moringa and sardine powders at molecular level

Protein: Moringa leaf powder is rich in proteins, particularly essential amino acids. The addition of moringa powder increases the protein content of noodles. At a molecular level, the proteins from moringa and sardine interact with the wheat gluten during dough formation, altering the protein network and enhancing the protein content of the final product (Gulzar *et al*., 2022).

Fat: Sardine powder contributes healthy fats, including omega-3 fatty acids. According to Yang *et al*. (2021), these fats can interact with the lipid components in the noodles, potentially altering the lipid

matrix and influencing the overall fat content. At a molecular level, lipids from sardine powder may form complexes with starch molecules, affecting the texture and lipid composition of the noodles.
Fiber: Moringa leaf powder contains dietary fiber, which can influence the texture and cooking properties of noodles. At a molecular level, fiber interacts with water and other components in the dough, affecting its rheological properties and contributing to the overall structure and texture of the noodles (Giuberti *et al*., 2021).

Minerals: Both moringa leaf and sardine powders are rich sources of minerals such as calcium, iron, and potassium. These minerals can interact with various components in the noodle matrix, influencing its nutritional profile and sensory attributes. At a molecular level, mineral ions may participate in enzymatic reactions during dough formation and cooking, impacting the texture, color, and flavor of the noodles (Kraithong *et al*., 2023).

Hardness and Cooking Loss: The addition of moringa and sardine powders can affect the textural properties of noodles, including hardness and cooking loss. Gong *et al*. (2024), revealed that at a molecular level, interactions between proteins, lipids, and carbohydrates during dough formation and cooking can influence the structural integrity and water-binding capacity of the noodles, thereby affecting their texture and cooking properties.

Aroma and Color: Moringa leaf and sardine powders contribute unique aroma compounds and pigments to the noodles, influencing their sensory characteristics. At a molecular level, volatile aroma compounds from moringa and sardine interact with other components in the noodles, contributing to their aroma profile. Similarly, pigments such as chlorophyll from moringa and carotenoids from sardine can impart characteristic colors to the noodles through molecular interactions with starch and protein molecules (Rao and Annadana, 2017). .

4.6 Rationale of the Study

The study on enhancing the nutritional content of noodles produced by small-scale processors in Tanzania through the incorporation of moringa and sardine powders fills several existing research gaps and addresses specific nutritional challenges faced by Tanzanian consumers. Firstly, it addresses the lack of research on innovative strategies to fortify staple foods like noodles with locally available nutrient-rich ingredients. By incorporating moringa and sardine powders, which are abundant in Tanzania, the study offers a cost-effective and sustainable approach to improving the nutritional quality of noodles. Additionally, the research contributes to addressing the prevalent deficiencies in essential nutrients, such as protein, vitamins, and minerals, in Tanzanian diets, particularly among vulnerable populations like children and adolescents. Through sensory evaluation and nutritional analysis, the study aims to provide evidence-based insights into the acceptability and nutritional benefits of fortified noodles, thus informing future interventions aimed at combating malnutrition and improving public health outcomes in Tanzania

4.7 Limitation of the study

i. Availability of Limited number of panelists participated on consumer test which could have been influence the results (sample size)

ii. The use of moringa and sardine powders were very new to the panelists and color and aroma resulted to poor sensory acceptability of noodles by consumers as the concentration of moringa and sardine powders increased

iii. No shelf- life study was conducted for the developed noodles while it is a very important aspect to be assessed for the developed product to understand its stability

CHAPTER FIVE

5.0 GENERAL CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In the pursuit of enhancing the nutritional content of noodles, the incorporation of moringa and sardine powders is being explored. The concentration of these additives plays a crucial role in determining the sensory characteristics of the fortified noodles. Different concentrations have distinct effects on colour, aroma, and overall preference. A balanced sensory profile was achieved when moringa leaf powder was incorporated at lower levels, specifically at 0.8%. This suggests that a moderate amount of moringa powder can be added without overpowering the product's sensory qualities.

On the other hand, higher concentrations of sardine powder had a significant impact on aroma and colour. This indicates that a stronger sardine flavour and colour can be achieved, which may appeal to a specific consumer segment with a preference for these characteristics.

Overall, this research offers valuable insights for product developers and food manufacturers interested in enhancing the nutritional components of noodles with moringa and sardine powders. By carefully adjusting the concentrations of these additives, they can create products that cater to different consumer preferences and potentially tap into new market segments. Additionally, understanding which sensory attributes have the most significant impact on consumer acceptance can guide product development and marketing strategies.

5.2 Recommendations

Further studies are recommended to optimize and standardize cooking techniques that could not affect the texture and cooking quality of the developed noodles.

The use of alternative ingredients rich in nutrients is recommended to mask the effect of colour and aroma and achieve the recommended dietary intake of adolescents via the consumption of noodles.

Further research could be done to explore novel ingredient combinations beyond moringa and sardine powders to maximize nutritional enrichment while maintaining sensory appeal

Noodle manufacturers are recommended to use a formulation containing 0.4% moringa leaf powder for 1 kg of wheat flour as they do not provide a colour and aroma effect.

Furthermore, conducting studies to evaluate consumer preferences across diverse demographic groups, including age, socioeconomic status, and geographical location, would provide valuable insights into the acceptability and market potential of fortified noodle products

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APPENDICES

Appendix 1: Consumer acceptability sensory evaluation questioner

Name of panelist…………………………………….

Age……………………………**Sex**……..

Paper number……………………………………

Date………………**Time**…………………………

You are provided with seven (7) dried noodle samples, please evaluate each coded sample provided and indicate how much you like or dislike each attribute of the sample by putting the most appropriate number (1-9) in the column against each attribute (Table 1.1) by using hedonic scale provided below

Hedonic scale

1 2 3 4 5 6
7 8 9

KEY: 1- Dislike extremely, 2-Dislike very much, 3-Dislike moderately, 4-Dislike slightly, 5- Neither like nor dislike, 6-Like slightly, 7-Like moderately, 8-Like very much, 9-Like extremely.

Indicate your degree of liking below

	Sample code						
Attribute	345	290	425	135	820	721	515
Color							
Aroma							
mouthfeel							
Taste							
Overall acceptability							

Other recommendations

……………………………………………………………………………

……………………………………………………………………………

Thank you

Appendix 2: **Quantitative Descriptive sensory evaluation form**

Panelist name………………………………………………..
Sex……………….………………………… Age…………………………
Time……….

You are provided with seven coded samples of dried noodles, please kindly evaluate the samples and indicate the intensity of each attribute as provided in the table 1.2 below using the line scale provided.

Color

Not at all 1 2 3 4 5
extremely colorfully

Aroma

Not at all 1 2 3 4

5 extremely smell

Saltiness

Not at all 1 2 3 4 5
extreme salty

Hardness

Very hard 1 2 3 4 5 extreme soft

	Sample code						
Attribute	135	721	345	820	515	290	425
color							
aroma							
saltiness							
hardness							

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.1/8/968 **Date:** 30th December, 2022

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. Victoria Thobias Mpalanzi** a bonafide **MSc. (Food Quality and Safety Assurance)** student with Registration number **MFQ/D/2021/0014** of SUA. By this letter **Ms. Victoria Thobias Mpalanzi** has been granted clearance to conduct research in the country. The title of the research in question is ***"ENHANCING NUTRITIONAL CONTENT OF NOODLES PRODUCED BY SMALL – SCALE PROCESSORS IN TANZANIA".***

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4. The period for which this permission has been granted is from **January, 2023** to **May, 2023**. The research will be conducted in **SUA- Morogoro, Morogoro Secondary in Morogoro Region and SGS – Environmental Laboratory - 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. Maulid W. Mwatawala
FOR: VICE-CHANCELLOR

VICE CHANCELLOR
SOKOINE UNIVERSITY OF AGRICULTURE
P.O.BOX 3000
MOROGORO, TANZANIA

c.c. Director, DPRTC, SUA. - To note in file.
c.c. Student – **Ms. Victoria Thobias Mpalanzi**

Appendix 4: **Turnitin Originality Report**

ENHANCING NUTRRITIONAL CONTENT OF NOODLES PRODUCED BY SMALL SCALE PROCESSORS IN TANZANIA

ORIGINALITY REPORT

27%	23%	17%	10%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	journalejnfs.com Internet Source	2%
2	www.suaire.sua.ac.tz Internet Source	1%
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7	researchspace.ukzn.ac.za Internet Source	<1%
8	Meng Niu, Gary G. Hou. "Whole grain noodles", Elsevier BV, 2020 Publication	<1%

Kuhusu Tasnifu Hii

Utafiti huu unalenga kushughulikia wasiwasi wa upungufu wa virutubishi unaosababishwa na matumizi ya tambi nchini Tanzania, ambayo yamekuwa maarufu kutokana na urahisi wa bei. Matumizi ya tambi yameongezeka kwa kasi, lakini bidhaa nyingi za tambi hazina virutubishi muhimu kama vitamini, madini, na protini ambayo husababisha upungufu wa lishe na matatizo ya afya. Utafiti huu unaangazia suluhisho kwa kuboresha tambi kwa kuongeza unga wa majani ya Mlonge na unga wa dagaa na kuzilenga kwa wazalishaji wadogo wa tambi. Matokeo ya utafiti huu yanaonyesha kuwa kuongeza unga wa majani ya Mlonge na unga wa dagaa kwenye tambi inaweza kuwa njia nzuri ya kuboresha muundo wao wa lishe. Hata hivyo, inasisitizwa kuzingatia usawa kati ya lishe na hisia za watumiaji. Kwa wazalishaji wa kiwango kidogo, utafiti huu unaweza kuwa chanzo cha ufahamu wa kuboresha tambi si tu kwa lishe bora bali pia kwa kuvutia kwa watumiaji, na hivyo kusaidia kuboresha chaguzi za chakula na kutatua changamoto za lishe. Kwa ujumla, utafiti huu unatoa ufahamu muhimu katika njia inayofaa ya kuboresha ubora wa lishe ya vyakula vya kawaida vinavyotumiwa nchini Tanzania na kuleta manufaa kwa tasnia ya chakula na watumiaji.