Original Research Article

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

ABSTRACT

Noodles with varying percentages of wheat flour, moringa leafand 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 i 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. 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

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 (Kamble *et al*., 2022). 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 (Ssaminato *et al*., 2021). 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 (Sissons, 2022).

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 (Alhassan *et al*., 2022). 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 (Olusanya, 2018). 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. *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 (Kaur *et al*., 2022).

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 (Nadeeshani *et al*., 2020). Sardines are especially valued for their high level of omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Chaula *et al*., 2023; Chaula *et al*.,2019) . These fatty acids are necessary for brain function, inflammation reduction, and heart health (Khalid *et al*., 2022). Sardines are also rich in a variety of vitamins and minerals, including vitamin D, vitamin B12, calcium, and selenium, which contributes to their nutritional (Refaat *et al*., 2022). Majumder and Balange. (2023) 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*. (2023) 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 (Mongi *et al*., 2013). 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 (Lawless and Heyman, 2013). Preference mapping describes which features led to consumer liking through the use of a visual representation that illustrates the relationship between descriptive sensory data and consumers' hedonic rankings (Giacalone *et al*., 2022).

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

MATERIALS AND METHODS

Samples Ccollection

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

Sample pPreparation

Preparation of Mmoringa Lleaf pPowder

Moringa leaf powder was made according to Orisa and Udofia. (2019); and Kumar. (2021) 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 (Mmodel 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.

Preparation of Ssardine Ppowder

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 60^0C 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 (Mamun *et al*., 2022).

Sample F~~f~~ormulation and ~~c~~Composition

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

Table 1: Composition of ~~n~~Noodles ~~i~~Incorporated with ~~m~~Moringa L~~l~~eaf ~~p~~Powder and ~~s~~Sardine ~~p~~Powder (g/100g)

Ingredients	Formulation ~~n~~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

Dried ~~n~~Noodle ~~p~~Preparation

The dried noodle preparation procedures were followed as described by Zula *et al*. (2021); 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^{0}C for further analysis and sensory evaluation.

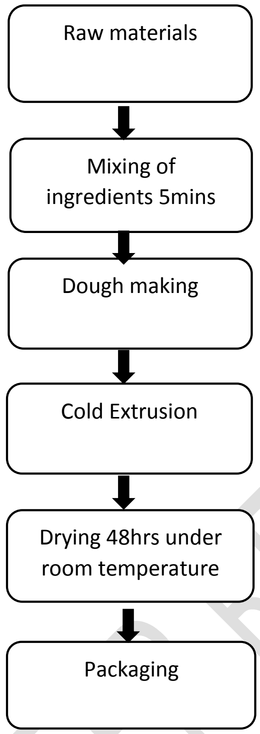

Figure 1: A flow diagram showing noodle preparation

Source: Mmodified from Orisa and Udofia. (2019)

Texture Aanalysis of nNoodles

The texture profile analysis was determined in accordance with coello *et al*. (2021); xu *et al*. (2020) with minor modifications. 20 g of noodles were cooked in 200 mL of water for 11 minutes using the kijdahl 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^{TM} 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 three times.

Cooking Qquality of dDried nNoodles

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. (2021); Pakhare *et al*. (2016). 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^{0}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.

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

Water Absorption Index

The water absorption index was calculated using the procedures described by Aydin and Gocmen. (2011); Shere *et al*. (2018) with minor modifications. 10 g of noodle sample was measured and placed in a conical flak, 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.

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

Volume Increase

The volume increase was determined using the procedures described by Kang *et al*. (2017); Shere *et al*. (2018) 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.

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

Sensory E~~e~~valuation

Quantitative D~~d~~escriptive ~~a~~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*. (2014); Lawless and Heymann, (2010) 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.

Table 2: Attributes, R~~r~~eferences and S~~s~~cales ~~d~~Developed in ~~q~~Quantitative ~~d~~Descriptive A~~a~~nalysis P~~p~~anel ~~t~~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

Hedonic TŧEst

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. (2013); Mongi *et al*. (2013).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.

Cooking of Nnoodles

Cooking procedures were followed with minor modifications as described by Zula *et al*. (2021). 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.

Statistical Ddata aAnalysis

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 regration (PLSR) was performed by unscrambler X software version 10.4 to check the relationship between quantitative descriptive data and consumer data.

RESULTS AND DISCUSSION

Textural ~~c~~Characteristics of ~~n~~Noodles

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

Table 3: Textural properties of cooked noodles

Sample	Hardness(g)	Cohesiveness	Springiness(mm)	Adhesiveness(mJ)
WC	64.7±2.5f[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[ij]	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±0.8a[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).

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 are present in the suppliments (moringa leaf powder and sardine powder). Similar result was observed in research done by Coello *et al*. (2021) 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 sudy of Weng *et al*. (2020) 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.

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 in Table 3 above show 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. This results abide with those of Coello *et al*. (2021) on pasta products enriched with moringa sprout powder as nutritive dense foods with bioactive potential who observed decrease in cohessiveness as moringa sprout powder increases. Khatkar and Kaur. (2018) 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. Accoding to the study of Ainsa *et al*. (2022), there was a decrease in cohessivevess of noodles incorporated with different concentration of fish-by product.

Springiness

Springiness refers to the ability of the noodle to regain its original shape after deformation. Pasqualone *et al*.(2016), 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 intergrity of protein-starch network hence resulting in lower values of springiness after cooking (Foschia *et al*., 2015). This results abide with Pasqualone *et al*. (2016), 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.

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 sligtht decrease in adhesiveness of noodles. Results abide with the study done by Nochai and Pongjanta. (2013) 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*. (2022) on quality parameters and technological properties of pasta enriched with a fish by-product who observed the increase of adhessivenes in pasta compared to control sample.

Table 4: Cooking Qquality of nNoodles Iincoporated with Mmoringa and SsardinesPpowders

Sample	Cooking lLoss%	Volume iIncrease%	Water Aabsorption%
WC	7.6±0.4^{a}	694.8±5.9^{f}	318.3±3.3^{s}
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^{ij}	294.7±4.7^{r}
WS2	25.2±0.8^{d}	226.5±5.6^{jk}	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).

Cooking lLoss

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 (Koh *et al*., 2022).

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*. (2021), 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*. (2020), 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. (2020);

Sholichah *et al*. (2021), 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.

Water ~~a~~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 (Shobha *et al*., 2021) .These findings abide with the study done by Desai *et al*. (2018) 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. (2021) 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.

Volume I~~i~~ncrease

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 above 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 (Kang *et al*., 2017). 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 5: Consumer ~~a~~Acceptability of ~~n~~Noodles ~~i~~Incoporated with ~~m~~Moringa and ~~s~~Sardine ~~p~~Powders

Sample	Color	Aroma	Mouth ~~f~~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^{tv}
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^{jkl}	6.2±2.3^{p}	6.2±2.3^{tv}
WM3	4.8±2.2^{ab}	5.4±2.3^{gh}	5.4±2.5^{jkl}	5.7±2.8^{np}	5.6±2.3^{stv}
WS1	5.9±2.2^{bc}	4.5±2.8^{fg}	4.7±2.7^{jk}	4.5±2.9^{mn}	5.4±2.6st
WS2	5.1±2.7^{bc}	3.9±2.6^{ef}	4.5±2.4^{jk}	3.9±2.9^{m}	4.4±2.7^{s}
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 ($p \leq 0.05$).

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).

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 (Corradini, 2019). 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*. (2021), 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*. (2020), 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, (2020) revealed that, there was a significant decrease in colour 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 colour of pizza decreases as dried cap fish powder increases (El-Beltagi *et al*., 2017).

Aroma

Aroma refers to an odour, 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 above. 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*. (2021) 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*. (2016), who obtained the successful overall liking with replacement of 20g/100g of wheat flour by tilapia flour however 30g/100g decreased overall liking.

MouthFfeel

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*. (2022), 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.

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*. (2021) 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, (2014), 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.

Overall Aacceptability

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 (Orisa and Udofia, 2019); 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 odour 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.

Quantitative Ddescriptive Aanalysis rResults

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^{df}	2.7 ± 1.5^{h}	3.3 ± 0.7^{k}
WM2	3.2 ± 0.6^{ab}	2.6 ± 1.3^{df}	2.5 ± 1.4^{h}	3.1 ± 1.1^{k}
WM3	3.4 ± 1.3^{ab}	2.8 ± 0.9^{df}	2.0 ± 0.0^{h}	3.3 ± 0.5^{k}
WS1	2.4 ± 1.4^{abc}	3.4 ± 0.7^{dfg}	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).

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 show no significant difference in colour intensity among themselves p>0.05 as it is shown in table 6 above 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 colour 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.

PCA Bi-plot

The bi-plot of principle component analysis (Figure 2) 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 colour 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, saltness, colour and aroma attributes as the elipse 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 saltness.

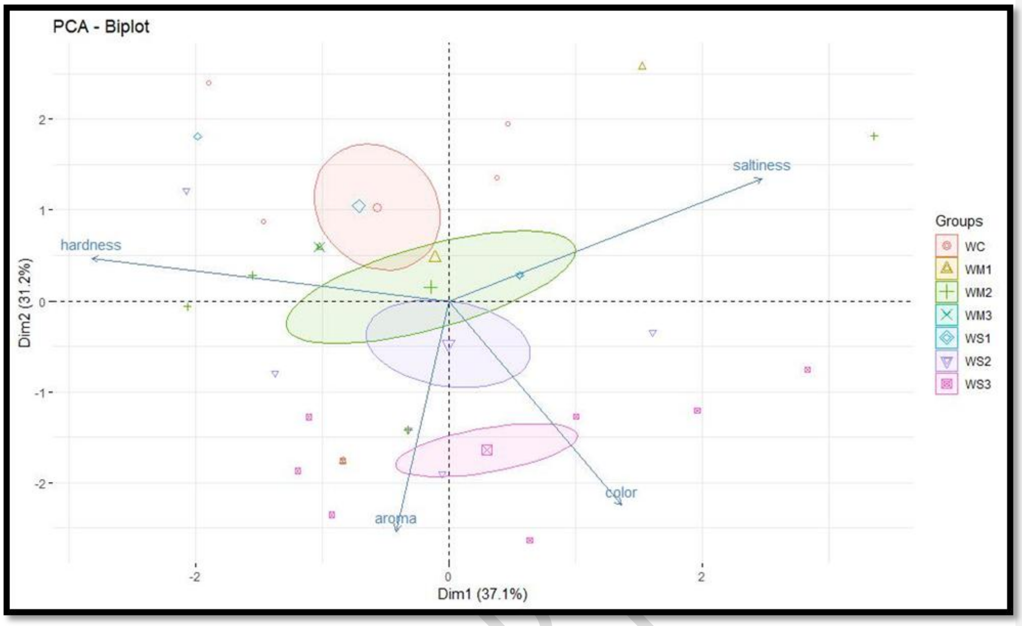

Figure 2: Bi- plot of PCA S~~s~~howing A~~a~~ssociation ~~b~~Between ~~a~~Attributes and S~~s~~ample

Relationship ~~b~~Between ~~q~~Quantitative ~~d~~Data and ~~h~~Hedonic ~~l~~Liking (~~c~~Consumer ~~d~~Data) by P~~p~~artial L~~l~~east S~~s~~quare R~~r~~egration (PLSR)

The score plot (Figure 3) and correlation loading plot (Figure 4) illustrate 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 figure 3, the correlation loading plot (Figure 4) 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. (2013); mongi and Gomezulu. (2022) 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.

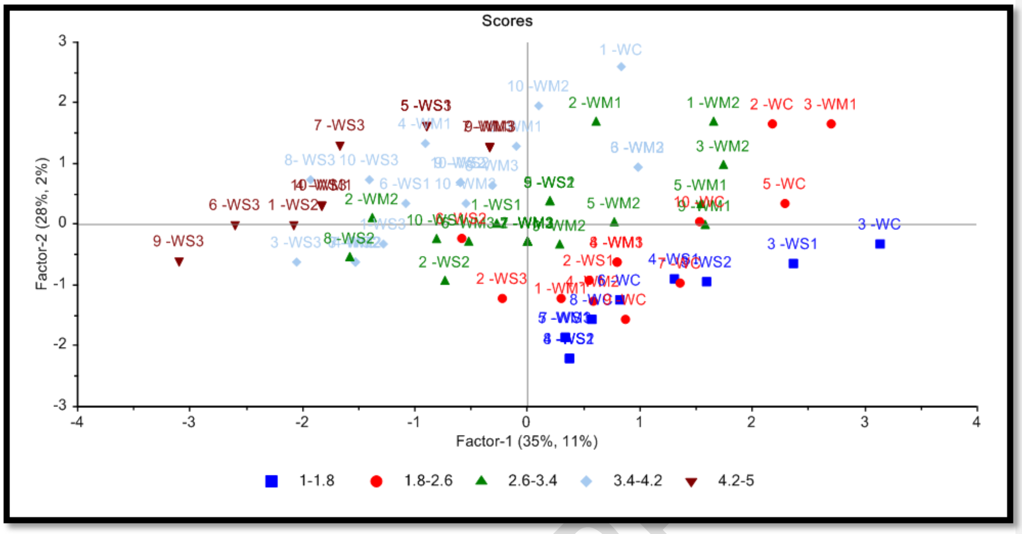

Figure 3: Score plot from a partial least squares regression of noodles incorporated with sardine and moringa leaf powders samples with descriptive data as X variables and hedonic rating as Y variables

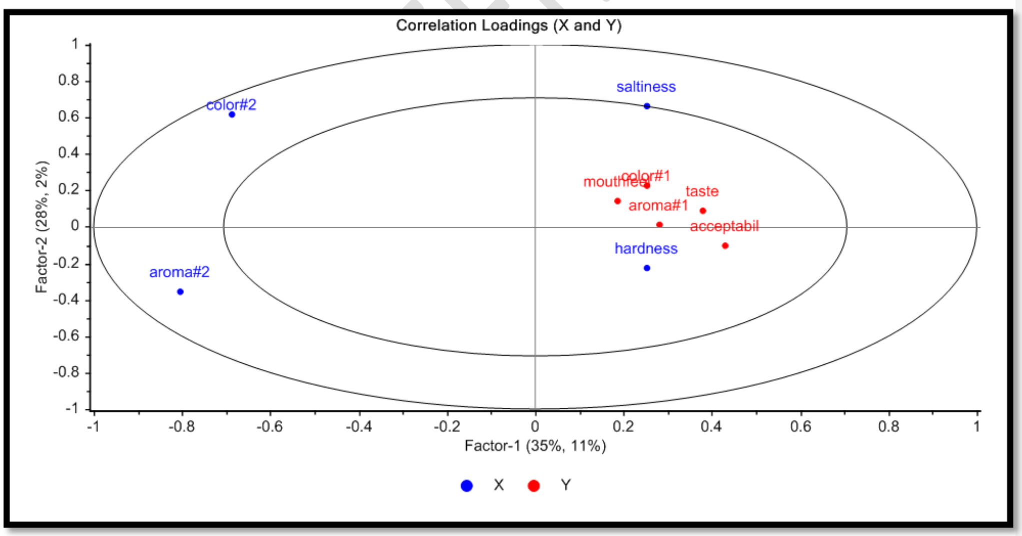

Figure 4: Correlation loadings from a partial least squares regression of noodles incorporated with sardine and moringa leaf powders samples with descriptive data as X variables and hedonic rating as Y variables

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 impated 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 poorely 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 inorder to improve the sensorial properties of the product as well as increasing nutritional conent.

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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 coloufully

Aroma

Not at all 1 2 3 4 5 extremely smell

Saltness

Not at all 1 2 3 4 5 extreme salty

Hardness

Very hard 1 2 3 4 5 extreme soft

Table 2: ~~q~~Quantitative Dd~~d~~escriptive ~~t~~Test

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