

The effect of rosemary, ginger, or garlic on microbial shelf life and sensory acceptability of nutritionally enriched cassava-based pancake (*Kabalagala*)

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ABSTRACT

Iron and vitamin A contents of Cassava-based pancake (*Kabalagala*), a delicacy among children in northern Uganda have recently been improved through the addition of biofortified iron-rich beans and orange-fleshed sweet potato. The nutritionally improved product (NIK) was designed as a strategy to address iron and vitamin A deficiencies which are endemic challenges among children in Uganda. However, the NIK had a lower microbial shelf life (24 h) than the original product (72 h). The objective of this study was to investigate the potential of the spices; rosemary, ginger, and garlic to improve the microbial shelf life of the NIK. Each of the spices was used individually to prepare NIK at a rate of 0.5, 0.75, and 1 %. The resultant products were evaluated for counts of total microbial load, *Enterobacteriaceae*, lactic acid bacteria, yeasts and molds as well as consumer sensory acceptability during storage at ambient temperature. Results of One-way Analysis of Variance (ANOVA) showed that all the spices exhibited potency against the microbial groups investigated only when included in the NIK at 0.75 % or 1 % ($p < 0.05$). The microbial shelf life of the NIK based on total microbial count increased from 24 to 72 h depending on the spice type and concentration. The spice, 1 % ginger resulted in *Enterobacteriaceae* and yeast and molds counts within acceptable microbial threshold for the entire storage time (72 h) with a maximum load of 3.41 and 2.82 log₁₀ CFU/g, respectively. The NIK containing ginger or garlic at 0.75 or 1 %, was more accepted and the extent of acceptability increased with storage time ($p < 0.05$). Based on the overall acceptability, the consumer acceptability varied from 1 % garlic >0.75 % garlic >1 % ginger >0.75 % ginger >0.5 % ginger in decreasing order. Spearman's correlation analysis revealed a strong association between the sensory parameters examined (appearance, aroma, texture, taste) and the overall acceptability of the products ($p < 0.05$). The magnitude of association between appearance, aroma, texture, taste and overall acceptability varied between 0.396–0.703, 0.504–0.679, 0.452–0.589, and 0.498–0.698, respectively. This study has demonstrated that ginger or garlic when applied at 0.75–1 % improves microbial shelf life of NIK concomitant with better consumer sensory acceptability. Therefore, ginger or garlic can be applied at 0.75–1 % to produce microbiologically and sensorially acceptable NIK for use to improve intake of vitamin A and iron among children in Uganda.

1. Introduction

Cassava-based pancake (*Kabalagala*) is a famous starchy food that is highly liked and commonly consumed as a breakfast menu by children in Uganda and as such has potential for nutrition intervention among children under five years. This is largely because vitamin A and iron deficiencies are high among children under five years and as per the most recent Uganda Demographic Health Survey, stood at 8.9 and 53 %, respectively (Ssentongo et al., 2020; Nabuuma et al., 2018). Owing to the high vitamin A and iron deficiencies among children under five years, a

recent study by Adoko et al. (2021) improved the vitamin A and iron content of *Kabalagala* by adding biofortified Orange Fleshed Sweet Potato (OFSP) and Iron-rich beans (IRB). The addition of OFSP and IRB increased the vitamin A and iron content of *Kabalagala* by 24, 421.22–2656.73 µg/100 g and 1.83–2.19 mg/100 g, respectively and were highly sensorially accepted among caregivers of children under five years (Adoko et al., 2021). However, improving the nutritional quality of the *Kabalagala* by Adoko et al. (2021) reduced its shelf life from 72 to 24 h thereby leading to increased food wastage due to spoilage, and also predispose consumers of the product beyond 24 h

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(shelf life) to infection from potential pathogens. The reduction in the shelf life of *Kabalagala* was majorly attributed to the increased proliferation of microorganisms owing to the increased nutrient content from OFSP and IRB, thereby leading to microbial-induced proteolysis and rancidity (Rathod et al., 2021). As such, reducing the microbial deterioration of *Kabalagala* (improving shelf life) is very essential for its application as a vitamin A and iron deficiency reduction strategy.

Spices are plant substances that are of indigenous or exotic origin that have aromatic or confer strong taste when added to food (Sah et al., 2020). They have been applied as natural food additives to improve the sensory characteristics as well as the microbial quality of foods for numerous centuries (Abd & Yousef, 2018; Utama-ang et al., 2020). Several spices such as ginger, rosemary, garlic, clove, mustard, cumin, thyme, oregano, black pepper, chili powder, and curry powder have demonstrated antimicrobial properties against microbes typical of bacteria, yeasts, and molds, (Abd & Yousef, 2018). The antimicrobial activity of spices largely depends on their concentration, the antimicrobial agents in a given spice and food matrix (Samah & Ahmed, 2019). Among the spices, garlic (*Allium sativum*), ginger (*Zingiber officinale*), and rosemary (*Salvia rosmarinus*) have in particular demonstrated greater inhibitory effects against *Bacillus cereus*, *Proteus mirabilis*, *Salmonella typhi*, *Staphylococcus aureus*, *E. coli*, *Clostridium perfringens*, and *Enterobacteriaceae* that are commonly implicated in food spoilage and infection associated with nutrient-rich foods (Baljeet et al., 2015; Nieto et al., 2018; El-Saber Batiha et al., 2021). This suggest that the extent of reduction of microbial load and associated shelf life by garlic, ginger, and rosemary in *Kabalagala* is likely to be affected by the food matrix.

Consumer sensory acceptability is an essential component of food product utilization and consumption, this is largely dependent on the ingredients used and preparation methods (Yang & Lee, 2019). As such, spices have been shown to influence the sensory acceptability of the products among consumers depending on the type and levels applied (Nieto et al., 2018; El-Saber Batiha et al., 2021). Considering that microbial shelf life (duration of time over the load of microbial a product falls within an acceptable microbial threshold) and consumer sensory acceptability are very vital for widespread application of *Kabalagala* as a strategy to improve vitamin A and iron, through increased intake among children under five years. This study, therefore aimed to investigate the potential of rosemary, garlic, and ginger to improve the microbial shelf life of nutritionally enriched cassava-based pancake (*Kabalagala*) and the associated consumer sensory acceptability during microbiologically acceptable shelf life.

2. Materials and methods

2.1. Experimental design

A completely randomized design was used to evaluate the effect of the spices (ginger, garlic, and rosemary) on the microbial load and consumer sensory acceptability of nutritionally enriched *Kabalagala*. The treatments were three levels (0.5, 0.75, and 1 %) of each of the three spices (ginger, garlic, and rosemary) and the control (0 % spice). The three levels of spices used was based on the findings of study by Paswan et al. (2021) and Ayari et al. (2020) which established that spices are generally added in the range of 0.5 to 1 %. The product was designed for children 48–60 months.

2.2. Raw materials

Raw materials, orange-fleshed sweet potato (*Naspot 13.0*), cassava (*Bao*), sweet bananas (*Kayinja Kiasubi*), and spices, ginger, rosemary, and garlic were purchased from local markets in Gulu and Omoro districts whereas iron-rich beans (*Narobeane 4C*) was purchased from National Agricultural Research Organization (NARO) in Kampala. The materials were transported to the experimental site and processed into flour using appropriate methods. Cassava tubers were processed into

flour according to the method described by Alamu et al. (2017). This method involves peeling the cassava tubers, washing, sorting, cutting, sun-drying, grinding, sifting, packing and finally storing the flour. For iron-rich beans, the seeds were washed, sun-dried, winnowed, and milled into flour. OFSP tubers were also sorted and washed, peeled, sliced, sun-dried, and ground into flour (Abdulkareem & Akhere, 2023).

Spices were prepared according to procedure of Regmia et al. (2021). In the case of rosemary, the leaves were washed, sun-dried, winnowed, and milled. Fresh ginger and garlic were also sorted, washed, peeled, sliced, sun-dried and milled. Milling of the dried spices into powder was done using a commercial grinder (Bear Electric Appliance, Guangdong, China) since spices in powder form can easily disperse into the flour and penetrate the final food product matrix (Gao et al., 2020). All the powders of the spices obtained were sieved using an Electronic spices sieving machine size 0.5 mm (Xinxiang Ltd, Henan, China) to obtain a size of less than 150 µm according to Etti et al. (2022). Flours were packed in high-density polyethylene (HDPE) bags and stored at room temperature (25–30 °C) till used within 1 to 15 days.

2.3. Product development

Making use of the flours for the ingredients produced under Section 2.2, nutritionally enriched *Kabalagala* products were prepared by involving the participation of women in the community who produce the product for sale. Specifically, the products were developed in the study communities (Gulu and Omoro districts). According to Adoko et al. (2021), the formulation of nutritionally enriched *Kabalagala* made of 33 % cassava, 43 % OFSP, 19 % IRB, and 5 % sweet banana designed for children 48–60 months was largely sensorially accepted by the community and was consequently used in this study. According to Paswan et al. (2021) and Ayari et al. (2020), spices are consumed in small quantities because of their strong aroma and flavor and are mainly used in a range of 0.5 to 1 % or 5000 to 10,000 parts per million (ppm) in a given food product. In this study, ten recipes of nutritionally enriched *Kabalagala* were prepared for children 48–60 months by adding rosemary, ginger, and garlic powder individually at 0.5, 0.75, and 1 % to the mixed flour. Nutritionally enriched *Kabalagala* formulated without spices (0 %) served as control. Table 1 summarises the inclusion levels of the various spices in the nutritionally enriched *Kabalagala*. Each product

Table 1
Levels of inclusion of ginger, rosemary, and garlic in nutritionally enriched *Kabalagala*.

Treatments	Formula identity	Mixing ratios (%) for various ingredients
Nutritionally enriched <i>Kabalagala</i> , no spices (control sample)	NK00	NK00 + 0 % spices
Nutritionally enriched <i>Kabalagala</i> , rosemary	NK11	NK00 + 0.5 % rosemary
Nutritionally enriched <i>Kabalagala</i> , rosemary	NK12	NK00 + 0.75 % rosemary
Nutritionally enriched <i>Kabalagala</i> , rosemary	NK13	NK00 + 1 % rosemary
Nutritionally enriched <i>Kabalagala</i> , ginger	NK21	NK00 + 0.5 % ginger
Nutritionally enriched <i>Kabalagala</i> , ginger	NK22	NK00 + 0.75 % ginger
Nutritionally enriched <i>Kabalagala</i> , ginger	NK23	NK00 + 1 % ginger
Nutritionally enriched <i>Kabalagala</i> , garlic	NK31	NK00 + 0.5 % garlic
Nutritionally enriched <i>Kabalagala</i> , garlic	NK32	NK00 + 0.75 % garlic
Nutritionally enriched <i>Kabalagala</i> , garlic	NK33	NK00 + 1 % garlic

Adapted with modification from Adoko et al. (2021). The Nutritionally enriched *Kabalagala* (NK00) was made of 43 % OFSP, 19 % IRB, 33 % cassava, and 5 % sweet banana.

type was prepared in triplicate. The preparation of nutritionally enriched *Kabalagala* followed the approach used by Adoko et al. (2021). This involves peeling and mashing the sweet bananas (50 g/ 1 kg of dough) and then adding flours for cassava, OFSP, IRB, and respective proportion of spices mixing while adding warm water until the dough was non-sticky. The dough obtained was cut into circular shapes of approximately 5.3 cm in diameter using Calliper and then fried at 150 °C for 3 min. The products were then cooled in an open-air as per the standard community practice, packed in food-grade plastic containers, and transported to the microbiology laboratory at Gulu University Multifunctional Research Laboratories for subsequent analysis.

2.4. Effect of the spices on microbial shelf life of nutritionally enriched *Kabalagala*

Microbial analyses were conducted using cultural methods as described by Jeršek (2022) and included: total microbial, *Enterobacteriaceae*, yeasts and molds and lactic acid bacteria counts. Lactic acid bacteria were included in addition to the major indicators of microbial quality (total microbial, *Enterobacteriaceae*, and yeasts and molds) because it is among the microorganisms that lead to food off flavors and gas formation that could affect sensory acceptability and hence use of the nutritionally enhanced pancake among the consumers. The analyses were performed at an interval of 12 h for 72 h (0, 12, 24, 36, 48, 60, and 72 h). In preparation for plating, 10 g of samples for each treatment was suspended in 90 ml of sterile buffered peptone water prepared by suspending 15 g in 1 L (BPW, HIMEDIA, M149I-500 G), and aseptically homogenized for 1 min at a speed of 8 strokes per second using a stomacher (Lab blenders Stomacher® 400 circulator- 0400/001/EU). The suspensions were further diluted in 0.1 % buffered peptone water seven-fold depending on the sample. The serially diluted samples of various dilution powers (1 mL) were each plated on plate count agar (PCA), potato dextrose agar (PDA), violet red bile glucose agar (VRBG) and de Man Rogosa Sharpe agar (MRS) for enumeration of total microbial count (TMC), yeasts and molds, *Enterobacteriaceae* and lactic acid bacteria counts, respectively. All media used were from HIMEDIA (Himedia Laboratories Pvt. Ltd., Mumbai, India). The sample preparation, serial dilution and inoculation were done under a Laminar flow hood (Air Science® LLC, Fort Myers, USA). The inoculated plates were incubated at 35 °C for 48 h, 25 °C for 5 days, 37 °C for 24 h, and 30 °C for 72 h for PCA, PDA, VRBG, and MRS, respectively. The microbial colonies were counted using a digital colony counter (Cole-Parmer™, St. Neots, United Kingdom). Each analysis was performed in duplicates and reported as log₁₀ colony forming units per gram (CFU/g). The microbial analyses of the nutritionally enriched *Kabalagala* for the four microbial groups were carried out at storage intervals of 0, 12, 24, 36, 48, 60, and 72 h yielding a total of 140 samples (Considering 10 treatments: 9 for the three spices and 1 for the control; 7 storage durations and; 2 replications).

2.5. Effect of addition of spices on consumer sensory acceptability of nutritionally enriched *Kabalagala*

Sensory evaluation was conducted in the Gulu and Omoro districts of northern Uganda. The districts were chosen because a previous study on *Kabalagala* was conducted in them (Adoko et al., 2021). The evaluation exercise was conducted using untrained panelists according to procedure described by Sharif et al. (2017) and Adoko et al. (2021). Panelists were volunteer processors of *Kabalagala* and women with children between 2 and 5 years who were willing to participate in the study. A multistage sampling technique method was used to select panelists. Two sub-counties were randomly chosen per district, followed by a random selection of two parishes from the selected sub-counties. From each of the two parishes, two villages were randomly chosen followed by a purposive selection of participants from households with children aged 2 to 5 years and those that process *Kabalagala*. This process led to the

selection of 94 panelists. This panelist size is consistent with Sharif et al. (2017) and Hough et al. (2006) who argued that, in consumer acceptability tests, taking into account the mean standard error and difference between the sample means of 10 % of the sensory scale, at least 50–150 panelists are required.

During the sensory evaluation, panelists were provided with samples and a score sheet. Each sample was coded with 3-digit random numbers and balanced ordered during testing to keep samples anonymous to avoid bias (Shikha et al., 2023). The five-point hedonic scale (1=dislike extremely, 2=dislike, 3=neither like nor dislike, 4= like 5= like extremely) was used to assess sensory attributes (appearance, aroma, texture, taste, and overall acceptability). Samples were served in pre-coded white disposable plates and mineral water for rinsing the mouth in between samples. An evaluation was conducted immediately after processing and then after every 12 h for 72 h of storage depending on the microbial shelf life point based on the total microbial count of a given recipe determined in Section 2.4. Panelists were placed at least 2 m apart to avoid interference and interaction among them.

2.6. Statistical analyses

Data were processed and analyzed using Statistical Package for Social Scientists (IBM® SPSS Statistics ver. 20, New York, USA). Data were checked for normality using Shapiro-Wilk and Kolmogorov-Smirnov tests ($p < 0.05$). At each sampling point during storage, the effect of the addition of each spice (rosemary, ginger, and garlic) on the microbial counts of nutritionally enriched *Kabalagala* and consumer acceptability score of the sensory parameters were analyzed using One-way analysis of variance (ANOVA). Means were separated using Tukey's Honestly Significant Difference test (HSD). Microbial shelf life was determined by expressing data on microbial load as line graphs in comparison to the microbiologically acceptable thresholds of 5.0, 4.0, 5.0, and 3.0 log₁₀ CFU/g for Total microbial count, *Enterobacteriaceae*, Lactic acid count, and yeast and molds counts obtained from ISO/ CODEX Standards DIS 20976-1 and Uganda National Bureau of Standards (UNBS). Correlations between the sensory attributes (appearance, aroma, texture, taste) and the overall acceptability were determined using Spearman's correlation test. For all analyses, statistical significance was attained at 5 % ($p < 0.05$).

3. Results and discussion

3.1. Effect of type and inclusion level addition of spices on the microbial shelf life of nutritionally enriched *Kabalagala*

3.1.1. Overall effect on counts of various microbial groups

The effect of the inclusion of spices in nutritionally enriched *Kabalagala* designed for children 48–60 months old on the overall load was largely observed at the inclusion level of 1 % (Table 2). This finding is in agreement with that of a study conducted by Udensi et al. (2012) which reported that adding higher spice levels significantly reduced microbial load and extended the shelf life of soymilk samples for five days when stored at ambient temperature. In terms of the microbial groups affected, the effect was not uniform but varied with the type of spice. Where effects were observed, compared to the control NK00 (0 % spices), counts of *Enterobacteriaceae* were reduced by all three spices, those of yeasts and molds were reduced by rosemary and garlic whereas those for total microbial count was reduced by garlic only ($p \leq 0.05$). In quantitative terms, reduction levels achieved were similar among microbial groups affected. For *Enterobacteriaceae*, counts were reduced by 1.46, 1.27, and 1.26 log₁₀ CFU/g for rosemary, ginger and garlic, respectively. In the case of yeasts and molds, compared to the control NK00 (0 % spices), the load was reduced by 1.02 and 1.06 log₁₀ CFU/g for rosemary and garlic, respectively, whereas for the total microbial count, the load was reduced by 2.02 log₁₀ CFU/g following the addition of garlic. The reduction in microbial load for respective microbial groups

Table 2
Effect of addition of various levels of spices on the overall microbial load of nutritionally enriched *Kabalagala* for children aged 48–60 months.

Treatment		Microbial load (Log ₁₀ CFU/g)			
		Total microbial count	<i>Enterobacteriaceae</i>	Lactic acid bacteria	Yeast and mold
Rosemary	NK00	5.90 ±2.02 ^a	4.01±1.29 ^a	5.39 ±1.75 ^a	3.04 ±1.30 ^a
	NK11	5.41 ±2.10 ^{ab}	3.20±0.93 ^{ab}	4.96 ±1.72 ^a	2.76 ±1.17 ^{ab}
	NK12	4.58 ±1.62 ^{ab}	2.92±1.00 ^{ab}	4.77 ±1.82 ^a	2.34 ±1.09 ^{ab}
	NK13	4.07 ±1.51 ^{ab}	2.55±1.15 ^b	4.32 ±1.62 ^a	2.02 ±0.97 ^b
Ginger	NK00	5.90 ±2.02 ^a	4.01±1.29 ^a	5.39 ±1.75 ^a	3.04 ±1.30 ^a
	NK21	4.96 ±1.87 ^{ab}	3.47±0.77 ^{ab}	5.12 ±1.62 ^a	2.83 ±1.25 ^{ab}
	NK22	4.43 ±1.33 ^{ab}	3.24±0.79 ^{ab}	4.93 ±1.54 ^a	2.35 ±1.02 ^{ab}
	NK23	4.04 ±1.20 ^{ab}	2.74±0.51 ^b	4.31 ±1.09 ^a	1.82 ±0.86 ^{ab}
Garlic	NK00	5.90 ±2.02 ^a	4.01±1.29 ^a	5.39 ±1.75 ^a	3.04 ±1.30 ^a
	NK31	4.90 ±1.67 ^{ab}	3.43±0.87 ^{ab}	4.72 ±1.54 ^a	2.68 ±1.15 ^{ab}
	NK32	4.38 ±1.46 ^{ab}	3.08±1.09 ^{ab}	4.48 ±1.61 ^a	2.35 ±0.99 ^{ab}
	NK33	3.88 ±1.16 ^b	2.75±1.28 ^b	4.06 ±1.36 ^a	1.98 ±0.82 ^b

Values indicate means ± Standard Deviation (*n* = 140, considering 10 treatments: 9 for the three spices and 1 for the control; 7 storage durations and; 2 replications). For each spice, values with different superscripts in the same column are significantly different at 5 % (*p* ≤ 0.05). Samples for each treatment were collected randomly and analyzed in duplicates. The *Kabalagala* was made of 43 % orange-fleshed sweet potato, 19 % iron-rich beans, 33 % cassava, and 5 % sweet banana. NK00: Control (0 % spices); NK11: 0.5 % rosemary; NK12: 0.75 % rosemary; NK13: 1 % rosemary; NK21: 0.5 % ginger; NK22: 0.75 % ginger; NK23: 1 % ginger; NK31: 0.5 % garlic; NK32: 0.75 % garlic and; NK33: 1 % garlic. CFU refers to colony-forming units per gram of sample.

with increasing spice concentration applied could be attributed to the proportional increase in the quantity of natural antimicrobial compounds added such as α-pinene, zingiberene and allicin in rosemary, ginger and garlic, respectively (Lv et al., 2018; Muhiyaldin et al., 2020). The aforementioned antimicrobial compounds have been reported to be effective against spoilage microflora and gram-positive and gram-negative bacteria such as Lactic acid bacteria, *Enterobacter* sp., and a number of yeast and molds (Odeyemi et al., 2020; Gottardi et al., 2016; Clemente et al., 2019). The antibacterial effect of rosemary, ginger, and garlic extract on certain pathogenic gram-positive and gram-negative bacteria investigated by earlier studies reported proportional increase in concentration of rosemary, ginger, and garlic extract with the antibacterial effect (Stojiljkovic, 2018; Aladağ et al., 2021; Beristain-Bauza et al., 2019; Fufa, 2019).

3.1.2. Effect on counts of various microbial groups during storage

Results on the effect of the addition of spices on the microbial counts as a function of time during storage of nutritionally enriched *Kabalagala* are presented in Fig. 1 (A–C). In general, irrespective of the microbial group, spice type, and concentration, microbial counts increased with storage time. However, the increase in counts was more pronounced for products containing lower concentrations of the spices. The increase in counts was highest for control products and lowest for products containing 1 % spices. Nonetheless, there were peculiarities among spices in the framework of the counts of various microbial groups reaching beyond the acceptable limits.

3.1.3. Effect of rosemary on the shelf life of the nutritionally improved *Kabalagala*

Results of the effect of the addition of rosemary on the microbial evolution concerning the shelf life of *Kabalagala* designed for children 48–60 months are presented in Fig. 1 (abcd). While the total microbial count of NK00 (control sample) reached the acceptability limit at 26 h of storage, samples containing 0.5, 0.75, and 1 % rosemary (NK11, NK12, and NK13) had acceptable total count levels up to 30, 42 and 54 h post incubation, respectively (Fig. 1a). Similar results were observed by Abedi et al. (2021) where treatment of fresh spinach with a whey protein edible biodegradable food packaging coating containing 0.6 % rosemary essential oil significantly reduced total bacterial counts in spinach. On the other hand, whereas counts of *Enterobacteriaceae* in the control product NK00 (0 % rosemary) reached acceptable limit at 44 h, *Kabalagala* containing 0.5, 0.75 % of the spice (NK11, NK12) reached the limit at 50, 60 h whereas the product NK13 (1 % rosemary) remained within acceptable limit for the entire storage time of 72 h (Fig. 1b). The findings of this study is in agreement with those of prior study in other food matrices. Significant (*p* < 0.05) reductions in *Enterobacteriaceae* counts in fermented sausages after superficial chitosan treatments with rosemary (0.2–1 %) were reported by Soncu et al. (2018). Application of rosemary at 1 % had a stronger antimicrobial effect on *Enterobacteriaceae* in sprouted mung beans unlike in the case of total microbial count (Alzowahi et al., 2013) although time taken to reach acceptable microbial threshold was not evaluated. Similarly, the effectiveness of rosemary essential oil were about 6 %, 11.1 %, and 16.7 % more in inhibiting psychrophile bacteria, thermophilic bacteria, and *Enterobacteriaceae*, respectively (Mavalizadeh et al., 2022). In the case of lactic acid bacteria (Fig. 1c) the counts in the control sample (NK00) were acceptable only up to 34 h, whereas the treated samples NK11, NK12, and NK13 were acceptable up to 36, 38, and 40 h post incubation, respectively. Unlike in this study where rosemary showed an insignificant reduction of lactic acid bacteria count, Badia et al. (2020) reported an increase in shelf life with the amount of rosemary essential oil in Tuscan sausage by 5 days upon reduction of lactic acid bacteria count by 1.5 log₁₀ CFU. The higher increase in shelf life based on the lactic acid bacteria count of Tuscan sausage than for nutritionally enriched *Kabalagala* could be attributed to the form in which the rosemary was applied. Whereas, in the current study, rosemary powder was used, in the study of Badia et al. (2020), extracted oil was used instead which could have resulted in a different extent of lactic acid bacteria inhibition because the active ingredient in rosemary (α-Pinene, 1,8-cineole, camphor, and borneol) is soluble in oil and could have led to its higher concentration in the oil (Xie et al., 2017). With regard to yeasts and molds, compared to the control NK00 (0 % spices), products containing 0.5, 0.75, and 1 % rosemary were acceptable up to 36, 48, and 60 h, respectively, which was much above that of control for which the longest limit of acceptance was 32 h (Fig. 1d). Results of this study showed that rosemary is an effective antifungal spice for controlling the growth of fungi in *Kabalagala* during storage at ambient temperature. Similarly, Azizkhani and Tooryan (2015) reported a significant reduction in fungal growth when rosemary extract was applied in beef sausage during storage relative to the control.

3.1.4. Effect of ginger on the shelf life of the nutritionally improved *Kabalagala*

Results on the effect of ginger on the microbial evolution and shelf life of *Kabalagala* designed for children 48–60 months are presented in Fig. 1 (efgh). In terms of total microbial count, the control sample (NK00) reached and exceeded the acceptable value of 5.0 log₁₀ CFU/g at 28 h with 5.79 log₁₀ CFU/g while NK21 (0.5 % ginger), NK22 (0.75 % ginger) and NK23 (1 % ginger) products had acceptable counts up to 38, 52 and 55 h of storage time, respectively (Fig. 1e). Ginger powder inhibits bacterial growth and development in soymilk with lower numerical values for the total bacteria on 0 day (2.4 log₁₀ CFU/g) to 3 days (3.8 log₁₀ CFU/g). Numerical values which are considerably low in the

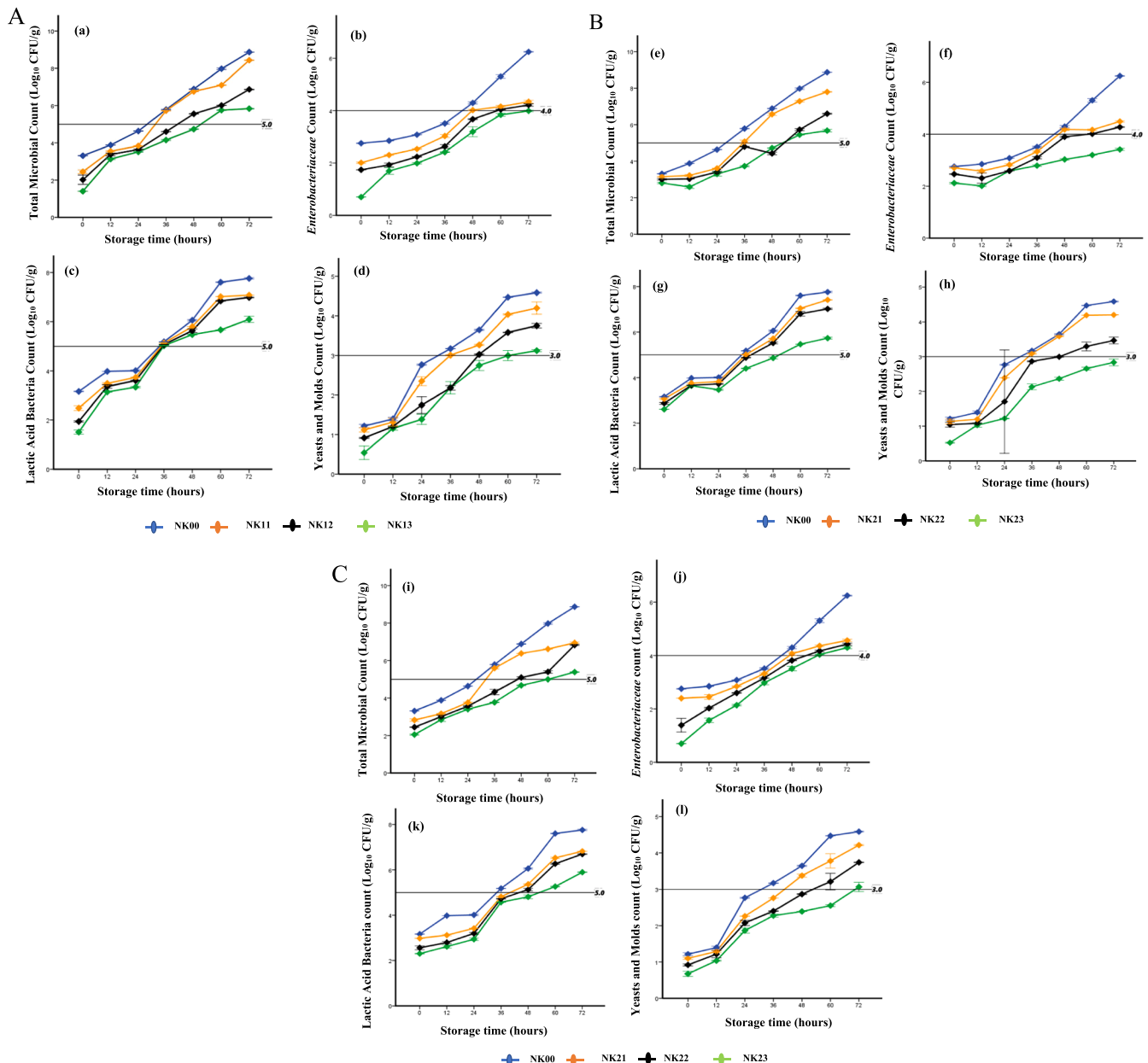


Fig. 1. Effect of rosemary (A) Ginger (B) and Garlic (C) on the microbial load in nutritionally enriched *Kabalagala* for children between 48 and 60 months stored at room temperature for 72 h. The *Kabalagala* was made with 43 % Orange Fleshed Sweet Potato, 19 % Iron-rich beans, 33 % cassava and 5 % sweet banana. (a), (e) and (i) effect of rosemary, ginger and garlic on Total microbial count, respectively; (b), (f) and (j) effect of rosemary, ginger and garlic on *Enterobacteriaceae*, respectively; (c), (g) and (k) effect of rosemary, ginger and garlic on Lactic acid bacteria, respectively; (d), (h) and (l) effect of rosemary, ginger and garlic on Yeasts and molds, respectively. NK00: 0 % spices; NK11: 0.5 % rosemary; NK12: 0.75 % rosemary; and NK13: 1 % rosemary; NK21: 0.5 % ginger; NK22: 0.75 % ginger; NK23: NK31: 0.5 % garlic; NK32: 0.75 % garlic; and NK33: 1 % garlic. Data points represent the mean of duplicate analysis of each sample and error bars indicate the standard deviation ($n = 56$, considering 4 treatments: 3 levels of garlic and 1 for the control; 7 storage durations and; 2 replications). CFU/g refers to colony-forming units per gram of sample.

soymilk sample with ginger powder show that ginger also has the antibacterial ability (Nadifah & Sari, 2016). With regards to *Enterobacteriaceae* count (Fig. 1f), the control sample NK00 and NK11 exceeded the acceptance limit ($4.0 \log_{10}$ CFU/g) at 44 and 46 h with $4.30 \log_{10}$ CFU/g and $4.19 \log_{10}$ CFU/g, respectively. However, product NK22 (0.75 % ginger) exceeded its acceptance limit at 61 h with $4.02 \log_{10}$ CFU/g while product NK23 (1 % ginger) remained acceptable for the entire storage duration ending with a load of $3.41 \log_{10}$ CFU/g that is below the limit at 72 h post incubation relative to NK00. Abolanle et al. (2017) reported that ginger when added at 2 % has a strong antimicrobial activity against *Enterobacteriaceae* and was observed in all treated *Tofu* (Beske) samples with shelf life being extended at ambient

temperature from 24 to 48 h to 120–240 h. The longer shelf life in the study of Abolanle et al. (2017) than in this study could be attributed to the higher level of ginger powder applied in the earlier (2 %) than in the latter study (0.5–1 %). In the case of lactic acid bacteria (Fig. 1g), counts of the organisms in NK00, NK21, and NK22 were acceptable till 34, 36, and 40 h post incubation, respectively, whereas counts in NK23 exceeded the acceptance limit after 52 h of storage period. Similarly, the reduction of lactic acid bacteria by ginger at 5 % (w/v) has previously been reported by Ire et al. (2017) in Tigmnut-Milk Drink. Growth of yeasts and molds was also reduced by the addition of ginger during storage (Fig. 1h). Compared with the control, the treatments NK11, and NK12 had lower yeasts and molds counts and remained acceptable up to

35 and 48 h, respectively. This was as opposed to product NK13 (1 % ginger) which had highest effect on growth of yeasts and molds and had counts of the organisms below the threshold limit till the end of the storage period. The antimicrobial efficiency of ginger against all tested microorganisms including yeast and mold can be attributed to the contents of sesquiterpene hydrocarbons α -curcumene and zingiberene (Beristain-Bauza et al., 2019; Wang et al., 2020) that are known to confer antimicrobial properties.

3.1.5. Effect of garlic on the shelf life of the nutritionally improved *Kabalagala*

Results showing the effect of garlic on the microbial evolution and shelf life of *Kabalagala* are presented in Fig. 1 (ijkl). Inclusion of garlic specifically at 1 %, showed the highest bacteria and fungi counts reduction in *Kabalagala*. For total microbial count (Fig. 1i), load in the control product (NK00) reached the tolerable limit ($5.0 \log_{10}$ CFU/g) at 28 h and surpassed it at 36 h with $5.79 \log_{10}$ CFU/g whereas products NK31 and NK32 (0.5 and 0.75 % garlic) had counts reaching acceptability limit at 32 and 48 h, respectively. However, NK33 (1 % garlic) remained acceptable up to 61 h but exceeded the tolerable acceptance limit after 72 h with $3.48 \log_{10}$ CFU/g reduction relative to NK00. The findings of the current study is in agreement with that of an earlier study. The addition of garlic to the marinade sauce at 10 % (w/w) successfully reduced the microbial load of lamb meat by 0.5 log CFU/g after 3 days of storage (Hajar-Azhari et al., 2023) although duration taken to exceed acceptable threshold was not determined.

With regard to *Enterobacteriaceae*, the counts in NK00 and NK31 exceeded the acceptance limit ($4.0 \log_{10}$ CFU/g) at 44 and 48 h with $4.30 \log_{10}$ CFU/g and $4.07 \log_{10}$ CFU/g, respectively, whereas products NK32 and NK33 reached and exceeded this limit after 55 and 60 h with 4.17 and $4.04 \log_{10}$ CFU/g, respectively (Fig. 1j). The finding of this study is comparable to those of Omara and Eljakee (2023) which revealed that the inhibition zone diameters (mm) of garlic oil in ready to eat (RTE) was 17 mm against *Enterobacteriaceae* and recommended its use as natural additives in RTE foods to reduce foodborne pathogens and improve shelf life. In the case of lactic acid bacteria (Fig. 1k), counts in the control sample NK00 reached and exceeded the acceptance limit at 35 h with $5.18 \log_{10}$ CFU/g whereas product NK31 (0.5 % garlic), NK32 (0.5 % garlic) and NK33 (1 % garlic) reached this limit value at 42, 47, and 55 h, respectively. These findings are similar to that of Horita et al. (2016) who reported that fresh garlic had excellent performance as an antimicrobial agent against lactic acid bacteria in Brazilian Frankfurters along the shelf life when applied at 1 %. Lastly, with regard to yeasts and molds (Fig. 1l), their counts in the control product (NK00) and garlic-treated products (NK31, NK32, and NK33) were acceptable up to 30, 42, 52, and 72 h of storage, respectively. Similarly, Arslaner (2020) reported that the addition of garlic in yogurt led to a significant decrease in the yeasts and molds counts compared to the control. The study revealed that addition of 1.0 % domestic garlic in yogurt reduce yeasts and molds counts by less than 1 log CFU/g after seven days of storage. This is in agreement with the highest effect observed with 1 % garlic used in this study but in disagreement with Kim et al. (2021) which reported freeze-dried garlic powder did not show any inhibition activity on yeasts and molds in *Kimchi*. This disparity among the studies could be due to the form of garlic used. Whereas the study by Kim et al. (2021) used freeze-dried garlic powder, the current study used fresh-dried garlic powder which could have led to disparity in the concentration of the inhibitory compounds in the garlic used between the two studies.

3.2. Effect of spices on sensory acceptability of nutritionally enriched *Kabalagala* during storage

3.2.1. Results on pooled data for microbiologically acceptable products

Consumer sensory acceptability of the nutritionally enriched *Kabalagala* samples was highly affected by the addition of the different types and levels of spices (Table 3). This study revealed that the texture and

Table 3

Effect of spices on sensory acceptability of nutritionally enriched *Kabalagala* during microbiologically acceptable shelf life.

Treatments	Sensory attributes based on data for accepted microbial shelf life samples during storage				
	Appearance	Aroma	Texture	Taste	Overall acceptability
NK00	4.20 $\pm 0.84^{ab}$	3.84 $\pm 0.97^{abc}$	3.82 $\pm 0.95^{ab}$	3.84 $\pm 1.09^{abc}$	4.11 ± 1.04^{ab}
NK11	3.86 ± 0.96^b	3.69 $\pm 0.97^{bc}$	3.73 $\pm 0.95^{ab}$	3.63 $\pm 0.95^c$	3.82 ± 0.87^{de}
NK12	4.03 $\pm 0.92^{ab}$	3.82 $\pm 0.94^{abc}$	3.78 $\pm 0.93^{ab}$	3.77 $\pm 1.07^{abc}$	3.92 $\pm 0.92^{bcde}$
NK13	4.14 $\pm 0.88^{ab}$	3.98 $\pm 1.05^{ab}$	3.80 $\pm 1.00^{ab}$	3.91 $\pm 1.03^{ab}$	4.05 $\pm 0.87^{abcd}$
NK21	3.96 $\pm 0.91^{ab}$	3.62 $\pm 1.01^c$	3.68 $\pm 0.93^b$	3.63 $\pm 1.02^c$	3.71 ± 0.85^e
NK22	4.16 $\pm 0.94^{ab}$	4.12 $\pm 1.86^a$	3.96 $\pm 0.92^a$	3.84 $\pm 1.06^{abc}$	4.10 ± 0.88^{abc}
NK23	4.27 ± 1.82^a	3.95 $\pm 1.07^{ab}$	3.75 $\pm 1.04^{ab}$	3.83 $\pm 1.10^{abc}$	4.03 $\pm 0.97^{abcd}$
NK31	4.14 $\pm 2.89^{ab}$	3.78 $\pm 0.99^{bc}$	3.74 $\pm 0.90^{ab}$	3.72 $\pm 0.91^{bc}$	3.86 ± 0.83^{cde}
NK32	4.07 $\pm 0.95^{ab}$	3.92 $\pm 0.99^{abc}$	3.79 $\pm 0.84^{ab}$	3.90 $\pm 0.99^{abc}$	3.99 $\pm 0.86^{abcd}$
NK33	4.27 ± 0.82^a	4.11 $\pm 0.99^a$	3.96 $\pm 0.93^a$	4.05 $\pm 0.97^a$	4.18 ± 0.82^a

Values indicate means $\pm$ Standard Deviation ($n = 658$). Values with different superscripts in the same column are significantly different at 5 % ($p \leq 0.05$). The *Kabalagala* was made of 43 % Orange Fleshed Sweet Potato, 19 % Iron-rich beans, 33 % cassava, and 5 % sweet banana. NK00: Control (0 % spices); NK11: 0.5 % rosemary; NK12: 0.75 % rosemary; NK13: 1 % rosemary; NK21: 0.5 % ginger; NK22: 0.75 % ginger; NK23: 1 % ginger; NK31: 0.5 % garlic; NK32: 0.75 % garlic; and NK33: 1 % garlic. Sensory data based on a 5-point hedonic scale.

taste of the control samples (0 % spices) were more accepted than those for *Kabalagala* with spices ($p < 0.05$). Overall, products containing 1 % garlic had the highest overall acceptability score followed by the control (0 % spices). This result is in line with the findings reported by Turan and Simsek (2022) which showed that pasturma cemen paste samples treated with 10 % garlic were more accepted than other spices treated samples. Additionally, another study conducted by Regu et al. (2016) revealed that the Ayib sample containing 5 % garlic had the second-highest overall acceptability score after the control. Generally, scores for all the sensory parameters for all the spice-treated products designed for children 48–60 months (Table 3), were identical to that of the control product (NK00) except for overall acceptability for which the score for products NK21 (0.5 % ginger), NK11 (0.5 % rosemary) and NK31 (0.5 % garlic) were significantly lower than that of the control ($p < 0.05$). This observation could be due to the familiarization of panelists with the product without spices and the high sensation of rosemary, ginger, and garlic which could have masked the taste and altered the texture. This assertion finds credence in the work of a previous study conducted by Balestra et al. (2011) who argued that the addition of spices in food results in less sensory acceptability when unpleasantness, bitter taste, sturdy spicy and texture of food samples are altered. Unlike texture and taste, appearance and aroma were generally similar. A comparison of products treated with spices revealed some differences among them. This was true for all the sensory parameters investigated. In the case of appearance, the parameter score for NK11 (0.5 % rosemary) was significantly lower than that recorded for either NK23 (1 % ginger) or NK33 (1 % garlic) by 0.41 score units. For aroma, the score for product NK21 (0.5 % ginger) was significantly lower than for product NK13 (1 % rosemary), NK22 (0.75 % ginger), and product NK33 (1 % garlic) by 0.36, 0.5, and 0.49 score units, respectively. Concerning texture, a difference was detected between products NK21 and NK22, and between NK21 and NK33. The score difference was 0.28 for both the former and latter comparisons. Taste had many inter-product

differences. There were three scenarios. Product NK13 (1 % rosemary) had a better score than product NK11 (0.5 % rosemary) by 0.28 units whereas product NK13 had better preference compared to product NK21 (0.5 % ginger) by the same score units. On the other hand, product NK21 was less preferred compared to product NK33 (1 % garlic) by 0.42 score units whereas the same outcome was observed between products NK31 and NK33 ($p < 0.05$). With respect to overall acceptability, it was apparent that consumers scored product NK21 (0.5 % ginger) lower than NK22 (0.75 % ginger), NK23 (1 % ginger), NK32 (0.75 % garlic), and NK33 (1 % garlic) by 0.39, 0.32, 0.28, and 0.47 points, respectively. The same trend was observed when comparing product NK11 (0.5 % rosemary) with NK22 (0.75 % ginger) or NK33 (1 % garlic) characterized by

a statistical difference of 0.28 and 0.36 score points, respectively ($p < 0.05$). Consumer sensory acceptability of food depends on several factors including a combination of the food properties, consumer's attitudes, knowledge, familiarity, traditional values, and the contextual effects in which consumption is taking place including environment, time, and social interaction (Torricco et al., 2019). As such the aforementioned factors could have contributed to the variations in sensory acceptability parameters observed among the treatments with spices in this study.

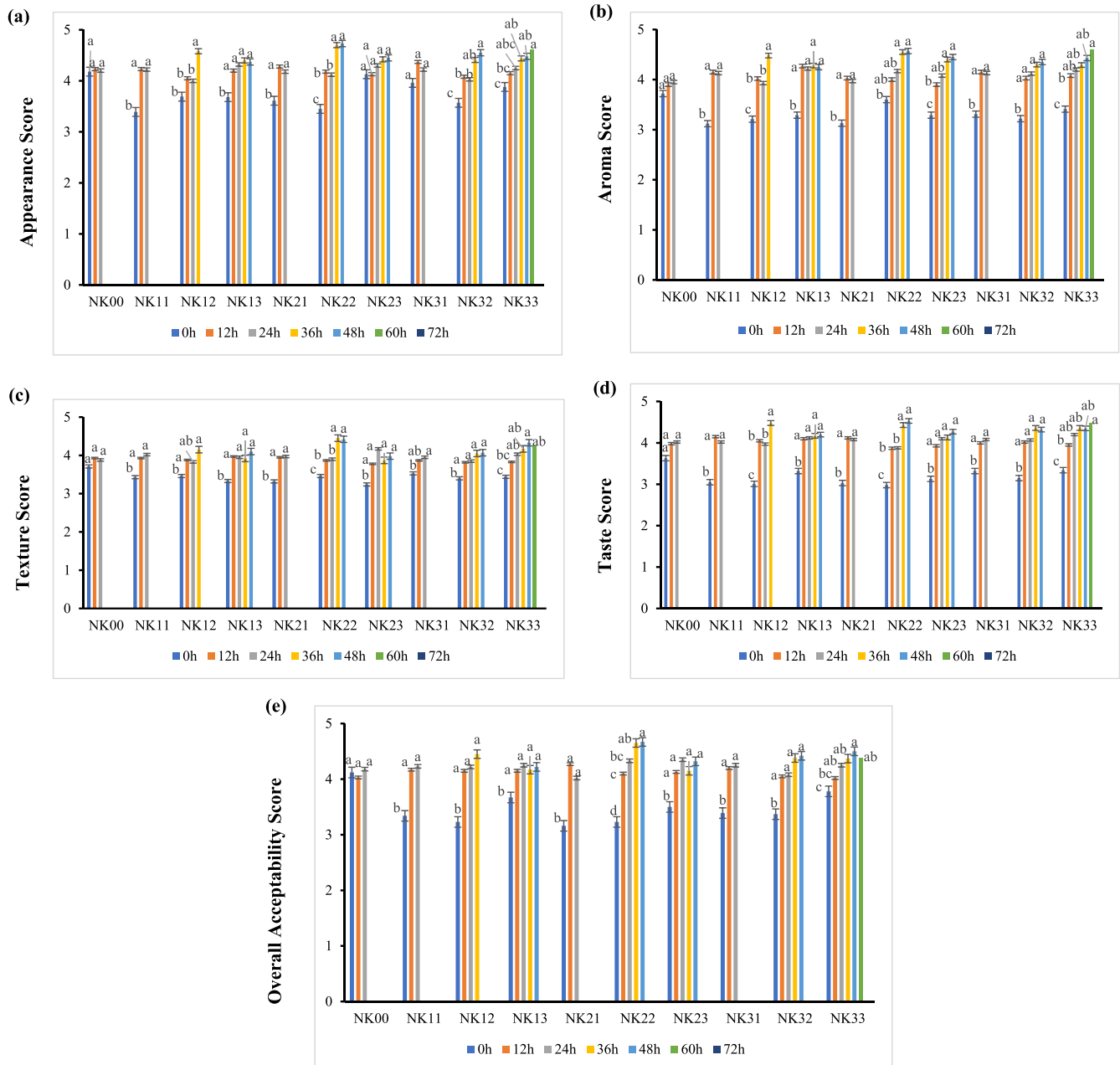


Fig. 2. Consumer sensory acceptability of nutritionally enriched *Kabalagala* for children between 48 and 60 months stored at room temperature for 72 h based on a 5-point hedonic scale. (a) Appearance; (b) Aroma; (c) Texture; (d) Taste and; (e) Overall acceptability. The data bar represents the mean score of each sample and error bars indicate the standard deviation. NK00: Control (0 % spices); NK11: 0.5 % rosemary; NK12: 0.75 % rosemary; NK13: 1 % rosemary; NK21: 0.5 % ginger; NK22: 0.75 % ginger; NK23: 1 % ginger; NK31: 0.5 % garlic; NK32: 0.75 % garlic and; NK33: 1 % garlic. The *Kabalagala* was made of 43 % Orange Fleshed Sweet Potato, 19 % Iron-rich beans, 33 % cassava, and 5 % sweet banana. Different letters among bars for each treatment for a specific sensory attribute show statistical significance at 5 % ($p < 0.05$).

3.2.2. Results comparing effects of spices on sensory score as a function of time

Results comparing the effects of spice treatments on sensory score as a function of time for products with acceptable microbial shelf life based on total microbial counts are presented in Fig. 2. Generally, consumer sensory score for the majority of sensory parameters increased with storage time in comparison to that of the control (0 % spices) albeit in a different pattern (Fig. 2 abcde). This observation could be due to consumer familiarization with the nutritionally enriched *Kabalagala* containing spices or a reduction in the strong sensation of the spices during storage while minimizing microbial-induced changes in organoleptic properties. However, the extent of the increase varied with the spice type. First, an increase in sensory acceptability was observed in 100 % of the treatments with different spices for aroma, texture, taste, and overall acceptability. However, for appearance, an increase in sensory score with storage time occurred among only 78 % of treatments with spices except for the treatments NK23 (1 % ginger) and NK31 (0.5 % garlic). Lastly, scores for none of the sensory attributes studied increased during the entire duration of storage for the control product (NK00). Similarly, Abdel-Naeem and Mohamed (2016) indicated that burger patties of all treated formulas with spices received higher scores for appearance, aroma/flavor, texture/tenderness, taste/juiciness, and overall acceptability during the whole storage time. A high acceptability score of the appearance, aroma, texture, taste, and overall acceptability of camel meat after treatment with ginger extract was also reported by Abdel-daem et al. (2014). The improvement in sensory attributes due to addition of rosemary, ginger, and garlic powder at 0.75 and 1 % in nutritionally enriched *Kabalagala* designed for children 48–60 months during storage suggest that the aforementioned levels of individual spices can be used to produce nutritionally enriched *Kabalagala* for children with high acceptability.

3.3. Association between sensory attributes and overall consumer acceptability of nutritionally enriched *Kabalagala* during storage

3.3.1. Results based on pooled data for the entire storage period

Generally, all the sensory attributes (appearance, aroma, texture, and taste) were positively and significantly correlated with overall acceptability irrespective of the type and level of application of the spices (Table 4). This finding concurs with those of a previous study which have documented that the acceptability of a given food depends on the preference of consumer for sensory attributes including appearance, aroma, taste, and texture (Maina, 2018). The magnitude of association between appearance or aroma and overall acceptability varied between 0.396–0.703 and 0.504–0.679, respectively. The appearance and aroma of treatment NK22 (0.75 % ginger) and NK12 (0.75 % rosemary) had the highest magnitude of correlation with overall

acceptability (0.703 and 0.679 respectively), whereas the control (NK00) ranked least in terms of association of both appearance and aroma with overall acceptability. The magnitude of association between texture and overall acceptability of all the spice-treated products varied by a small magnitude (0.452–0.575). Taste of all the treatments had a strong positive correlation with the overall acceptability by a magnitude greater than 0.5 except in NK13 (1 % rosemary) whereas NK12 (0.75 % rosemary) had the highest degree of association with overall acceptability. The findings of this study is in disagreement with that of an earlier study by Caracciolo et al. (2020) which reported that consumer acceptability of microgreens was largely influenced by their aroma and texture only even though the appearance of the microgreens was largely appreciated. The disparity between the findings of the study by Caracciolo et al. (2020) and those of the current study could be attributed to variation in the extent to which the sensory panelist attach importance to appearance as a product acceptability dimension. This therefore implies that the influence of appearance, aroma, taste, and texture on overall acceptability is context-specific depending on the food type in question.

3.3.2. Correlation between sensory attributes and overall acceptability as a function of storage time

The sensory attributes examined had a positive and significant correlation with overall acceptability irrespective of the type and levels of spices at each storage time cluster (Table 5). At 0 h, sensory attributes of all the treatments were significantly associated with the overall acceptability ($p < 0.05$). The appearance of NK23 (1 % ginger) and aroma of NK22 (0.75 % ginger) had the strongest correlation with the overall acceptability indicated by correlation coefficients of 0.551 and 0.611, respectively. The texture of all the treatments had a low positive correlation with the overall acceptability except for NK00 (control sample) which was above 0.5. At 12 h, similar observations were made as in the case of 0 h with all the attributes being significantly associated with overall acceptability except that of texture for NK31 (0.5 % garlic). From 24 h to 48 h, all the sensory attributes had a positive and significant correlation ($p < 0.05$) with the overall acceptability except the taste of NK13 (0.5 % rosemary) at 24 h. However, at 60 h, only the aroma of NK33 (1 % garlic) significantly influenced overall acceptability. This observation suggests that at 60 h of storage, appearance, texture, and taste characteristics are not important for the acceptability of nutritionally enriched *Kabalagala* for children 48–60 months. The disparity in the moderating role of appearance, texture, and taste on overall acceptability of the nutritionally enriched *Kabalagala* during storage could be due to the differential effect of the spices on appearance, texture, and taste in the different food matrices. Indeed, this argument finds credence in the work of Shittu and Adedokun (2010) which reported that the odour of cooked *Pupuru* and *Lafun* samples did not have

Table 4

Correlation between sensory attributes and overall acceptability of nutritionally enriched *Kabalagala* for children 48–60 months based on pooled data for the entire storage period.

Treatment	Overall acceptability score	Appearance Score	r	Aroma Score	r	Texture Score	r	Taste Score	r
NK00	4.11	4.20	0.396**	3.84	0.504**	3.82	0.554**	3.84	0.545**
NK11	3.82	3.86	0.613**	3.69	0.590**	3.73	0.566**	3.63	0.673**
NK12	3.92	4.03	0.593**	3.82	0.679**	3.78	0.526**	3.77	0.698**
NK13	4.05	4.14	0.595**	3.98	0.544**	3.80	0.463**	3.91	0.498**
NK21	3.71	3.96	0.524**	3.62	0.577**	3.68	0.589**	3.63	0.681**
NK22	4.10	4.16	0.703**	4.12	0.678**	3.96	0.575**	3.84	0.670**
NK23	4.03	4.27	0.590**	3.95	0.608**	3.75	0.567**	3.83	0.610**
NK31	3.86	4.14	0.586**	3.78	0.621**	3.74	0.452**	3.72	0.600**
NK32	3.99	4.07	0.548**	3.92	0.631**	3.79	0.565**	3.90	0.662**
NK33	4.18	4.27	0.520**	4.11	0.541**	3.96	0.482**	4.05	0.521**

Scores with ** are statistically significant at a 5 % level of confidence. ‘r’ refers to the correlation coefficient. The acceptability score is based on a 5-point hedonic scale. NK00: Control (0 % spices); NK11: 0.5 % rosemary; NK12: 0.75 % rosemary; NK13: 1 % rosemary; NK21: 0.5 % ginger; NK22: 0.75 % ginger; NK23: 1 % ginger; NK31: 0.5 % garlic; NK32: 0.75 % garlic and; NK33: 1 % garlic. The *Kabalagala* was made of 43 % Orange Fleshed Sweet Potato, 19 % Iron-rich beans, 33 % cassava, and 5 % sweet banana.

Table 5

Correlation between sensory attributes and overall acceptability at each sampling point for products designed for children 48–60 months.

Treatment	Overall Acceptability Score	Appearance		Aroma		Texture		Taste	
		Score	r	Score	r	Score	r	Score	r
0 h									
NK00	4.12	4.18	0.464**	3.72	0.572**	3.71	0.532**	3.63	0.626**
NK11	3.34	3.39	0.354**	3.12	0.378**	3.43	0.388**	3.05	0.449**
NK12	3.23	3.69	0.341**	3.21	0.571**	3.46	0.358**	3.01	0.533**
NK13	3.67	3.68	0.484**	3.29	0.308**	3.33	0.320**	3.32	0.442**
NK21	3.16	3.61	0.301**	3.13	0.354**	3.32	0.390**	3.03	0.426**
NK22	3.23	3.45	0.389**	3.60	0.611**	3.46	0.374**	2.98	0.438**
NK23	3.50	4.13	0.551**	3.29	0.587**	3.24	0.293**	3.13	0.498**
NK31	3.39	3.96	0.307**	3.31	0.454**	3.53	0.286**	3.32	0.462**
NK32	3.37	3.57	0.317**	3.22	0.363**	3.40	0.366**	3.15	0.582**
NK33	3.78	3.88	0.496**	3.41	0.502**	3.44	0.320**	3.34	0.453**
12 h									
NK00	4.03	4.23	0.402**	3.90	0.586**	3.93	0.594**	3.98	0.474**
NK11	4.17	4.23	0.522**	4.15	0.451**	3.93	0.480**	4.15	0.459**
NK12	4.15	4.05	0.469**	4.02	0.543**	3.88	0.473**	4.05	0.555**
NK13	4.15	4.20	0.504**	4.27	0.353**	3.97	0.555**	4.10	0.547**
NK21	4.27	4.28	0.485**	4.03	0.398**	3.95	0.504**	4.12	0.713**
NK22	4.10	4.18	0.490**	4.00	0.470**	3.87	0.390**	3.87	0.522**
NK23	4.13	4.13	0.399**	3.90	0.526**	3.78	0.537**	3.93	0.472**
NK31	4.20	4.37	0.514**	4.15	0.484**	3.87	0.235	4.00	0.487**
NK32	4.05	4.08	0.299*	4.03	0.546**	3.82	0.560**	4.02	0.372**
NK33	4.02	4.15	0.444**	4.08	0.379**	3.83	0.529**	3.95	0.421**
24 h									
NK00	4.18	4.20	0.293*	3.95	0.334**	3.88	0.623**	4.02	0.584**
NK11	4.23	4.22	0.628**	4.13	0.447**	4.02	0.604**	4.02	0.608**
NK12	4.22	4.00	0.630**	3.93	0.561**	3.83	0.505**	3.97	0.661**
NK13	4.25	4.32	0.445**	4.22	0.472**	3.95	0.371**	4.12	0.235
NK21	4.02	4.18	0.524**	3.97	0.588**	3.97	0.607**	4.08	0.604**
NK22	4.33	4.12	0.439**	4.17	0.572**	3.90	0.420**	3.88	0.541**
NK23	4.35	4.30	0.441**	4.08	0.587**	4.17	0.648**	4.10	0.552**
NK31	4.25	4.22	0.633**	4.13	0.491**	3.95	0.647**	4.08±	0.447**
NK32	4.08	4.03	0.445**	4.12	0.545**	3.85	0.493**	4.07	0.472**
NK33	4.25	4.25	0.375**	4.20	0.382**	4.03	0.512**	4.20	0.465**
36 h									
NK12	4.45	4.58	0.564**	4.48	0.515**	4.15	0.501**	4.48	0.453**
NK13	4.17	4.40	0.700**	4.28	0.650**	3.92	0.481**	4.17	0.548**
NK22	4.65	4.70	0.805**	4.55	0.459**	4.45	0.445**	4.43	0.362**
NK23	4.15	4.42	0.750**	4.40	0.570**	3.87	0.669**	4.13	0.584**
NK32	4.38	4.41	0.512**	4.30	0.492**	4.05	0.633**	4.36	0.615**
NK33	4.37	4.44	0.609**	4.29	0.578**	4.17	0.578**	4.36	0.605**
48 h									
NK13	4.22	4.37	0.772**	4.25	0.764**	4.10	0.440**	4.20	0.465**
NK22	4.67	4.73	0.764**	4.57	0.441**	4.42	0.384**	4.53	0.353**
NK23	4.32	4.45	0.686**	4.45	0.486**	3.98	0.645**	4.27	0.693**
NK32	4.42	4.55	0.637**	4.35	0.515**	4.07	0.477**	4.32	0.551**
NK33	4.50	4.48	0.599**	4.43	0.616**	4.33	0.508**	4.35	0.467**
60 h									
NK33	4.38	4.62	0.244	4.60	0.416**	4.25	0.041	4.47	0.235
72 h									
NA	NA	NA	–	NA	–	NA	–	NA	–

Scores with ** are statistically significant 5 % level of confidence. ‘r’ refers to the correlation coefficient. The *Kabalagala* was made of 43 % orange-fleshed sweet potato, 19 % iron-rich beans, 33 % cassava, and 5 % banana. NK00: Control (0 % spices); NK11: 0.5 % rosemary; NK12: 0.75 % rosemary; NK13: 1 % rosemary; NK21: 0.5 % ginger; NK22: 0.75 % ginger; NK23: 1 % ginger; NK31: 0.5 % garlic; NK32: 0.75 % garlic; NK33: 1 % garlic. NA means the sample was not tested. The acceptability score is based on the 5-point hedonic scale.

any significant influence on the consumer overall acceptability but was significant in the case of *Fufu* samples. These findings suggest that rosemary, ginger and garlic can be applied to improve sensory attributes of nutritionally enriched *Kabalagala* during storage for up to 48 h.

4. Conclusion

The findings of this study have demonstrated that the spices; rosemary, ginger, and garlic reduced the growth of specific microbial groups, extended the microbial shelf life and enhanced sensory acceptability of nutritionally enriched *Kabalagala* for children aged 48–60 months during storage at ambient temperature by different extents. The levels of spices affected the microbial load of total microbial, *Enterobacteriaceae*, lactic acid bacteria, and yeasts and molds as well as the

sensory acceptability. The reduction of total microbial, *Enterobacteriaceae*, lactic acid bacteria, and yeasts and molds counts during storage increased with an increase in the quantity of each spice applied. Ginger and garlic inclusion at 1 % showed the highest level of antimicrobial activity against all the microbial groups investigated and subsequently extended the shelf life of nutritionally enriched *Kabalagala* for children aged 48–60 months by 55 and 61 h (based on total microbial count), respectively. Consumer sensory acceptability (appearance, aroma, texture, taste, and overall acceptability) was improved by the addition of the spices in the nutritionally enriched *Kabalagala* with microbiologically accepted shelf life during storage. However, *Kabalagala* containing 1 % garlic was the most acceptable followed by the control and 0.75–1 % ginger in decreasing order of magnitude. In addition, all the sensory attributes including appearance, texture, and taste of nutritionally

enriched *Kabalagala* accounted for the overall product acceptability during the entire storage period except at 60 h. Based on the findings of this research, the following is recommended, the inclusion of 1 % garlic or 0.75–1 % ginger should be promoted among rural households to improve microbial shelf life and consumer sensory acceptability of nutritionally enriched *Kabalagala* for increased iron and vitamin A intake among children 48–60 months old. Considering that the effects of spices were evaluated individually, there is need to: (i) optimize the levels of rosemary, ginger, and garlic for synergistic effect when added to nutritionally enhanced product (*Kabalagala*) for microbial reduction and consumer sensory acceptability; (ii) identify the dominant species in each microbial group and examine the differential effect of the spices on each of them and; (iii) investigate socio-demographic factors that influence acceptability. This is essential in the promotion of nutritionally enriched *Kabalagala*.

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Ethical statement

This article does not contain animal studies. This article had the participation of humans as sensory panellists who participated voluntarily and were knowledgeable of the entire experiment. The study was explained to consumers and they were informed that they would participate in the sensory evaluation by rating the products using different sensory attributes (appearance, texture, aroma, taste, and overall acceptability). Full consent of the participants was sought before participation in the sensory evaluation and each panellist signed a consent form before participating in the study. Participants gave informed consent via the statement "I am aware that my responses are confidential, and I agree to participate in this survey" where an affirmative reply was required to enter the survey. They were compensated for their participation with soap costing the amount of 3 USD. Ethical clearance was obtained from Gulu University Research Ethics Committee (Approval number: GUREC 15/03/2021). Additional authorisation to conduct research in the community was obtained from the Chief Administrative Officer of Gulu and Omoro districts.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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