International Journal of Gastronomy and Food Science 41 (2025) 101271

Contents lists available at ScienceDirect

International Journal of Gastronomy and Food Science

journal homepage: www.elsevier.com/locate/ijgfs

Sensory evaluation of composite porridges based on pearl millet and cowpea for Mozambican children under five years old

Sunera Nurmomade [a,b,*], Maria Eduardo [b], Santanu Basu [a], Irene de Carvalho [b], Roger Andersson [a], Karin Wendin [c]

[a] Department of Molecular Sciences, Swedish University of Agricultural Sciences, Box 7015, SE-750 07, Uppsala, Sweden
[b] Department of Chemical Engineering, Eduardo Mondlane University, Box 257, Maputo, Mozambique
[c] Department of Food and Meal Science, Kristianstad University, SE- 291 88, Kristianstad, Sweden

ARTICLE INFO

Keywords:
Composite porridge
Pearl millet
Cowpea
Sensory evaluation
Children undernutrition

ABSTRACT

Undernutrition remains a major public health problem in Mozambique. Traditional porridges made from cereals like maize, rice, and millet are typically low in protein, nutrient density, and energy content. This study aimed to evaluate caregivers' liking of newly developed composite porridge made with pearl millet and cowpea, formulated to meet the nutritional needs of children by enhancing protein content and nutrient density.

Sensory evaluations were conducted in three distinct locations: Copuito, Pulupu, and Nanguasse in Cabo Delgado Province, Mozambique. Four porridges were tested for appearance, colour, aroma, and taste: (1) **SM** - 100 % soaked pearl millet (control); (2) **FMFP** - 60 % fermented pearl millet + 40 % fermented cowpea; (3) **FGMFP** - 55 % fermented pearl millet + 5 % germinated pearl millet + 40 % fermented cowpea; and (4) **FMFGP** - 60 % fermented pearl millet + 35 % fermented cowpea +5 % germinated cowpea.

Results showed that caregivers in all locations liked FMFGP very much, with both SM and FMFGP described as "good porridge". Although all composite porridges were generally liked, FMFP and FGMFP were less liked in Copuito and Pulupu because of their thinner viscosity and the taste of beans. The thin viscosity was due to the addition of germinated pearl millet, which allows for an increase in energy density. Overall, FGMFP and FMFGP have the potential to be successfully introduced and used as a nutritional solution to address children's malnutrition in Mozambique.

1. Introduction

Porridge, a staple meal made from cereals like maize, rice and millet, is commonly given to children in developing countries, including Mozambique. However, this porridge is often too viscous, making it hard for children to swallow and digest, and usually it is low in protein and energy density. When the porridge is diluted with water, there is a reduction in its nutrient content (Makame et al., 2020; Onofiok and Nnanyelugo, 1998). Many caregivers, unfortunately, prepare cereal porridge that lacks energy, protein and other nutrients. To overcome these concerns, optimizing a composite porridge made from cereal and an affordable source of protein like legumes and using pre-treated flour can be an alternative approach. Griffith et al. (1998), Singhavanich et al. (1999) and Thaoge et al. (2003) showed that using pre-treated flour could reduce porridge viscosity while enhancing nutrient and energy density. When porridge reduces the viscosity, it opens the possibility of adding more flour, ultimately leading to high-energy-density porridge and an improved food source for children.

Inadequate intake of nutrients stands as a critical contributor to undernutrition in developing countries, as highlighted by Saaka et al. (2021). Undernutrition significantly impacts public health in Africa, causing stunted growth and impaired development among children under the age of five(United Nations Children's Fund, 2023). In Mozambique, approximately 37 % of children under the age of five suffer from chronic malnutrition, which is commonly due to a lack of protein and micronutrients, with higher rates most widely observed in the northern region, specifically in Cabo Delgado Province (INE/ICF, 2023).

Recent research highlights the significant benefits of incorporating legumes and pre-treated flour into traditional cereal porridges. By combining legumes with pre-treated flour, protein quality is enhanced, in addition to an improvement in protein content. When legumes and

* Corresponding author. Department of Molecular Sciences, Swedish University of Agricultural Sciences, Box 7015, SE-750 07 Uppsala, Sweden.
E-mail address: sunera.zulficar.nurmomade@slu.se (S. Nurmomade).

https://doi.org/10.1016/j.ijgfs.2025.101271
Received 6 February 2025; Received in revised form 30 July 2025; Accepted 12 August 2025
Available online 13 August 2025
1878-450X/

pre-treated flour are added to cereal porridge, they also lower the viscosity and reduce the dietary components to increase nutrient density and bioavailability (Moriconi et al., 2023; Nout and Ngoddy, 1997; Oladiran and Emmambux, 2022).

A composite porridge made from pearl millet and cowpea can be a potential choice to improve the nutritional status of undernourished children in Mozambique. Pearl millet and cowpea are climate-resilient crops that are cultivated and consumed in many parts of developing countries, including Mozambique. These crops are affordable and available in the northern region of Mozambique, making them good candidates for preparing composite porridges for children to improve their nutritional status.

Twelve different composite porridges with varying proportions of pre-treated pearl millet and cowpea flour were developed and tested in our laboratory. Both crops are excellent sources of energy, and their combination provides an affordable source of protein. Pearl millet, variety Changara contains 12.8 % of crude protein content and cowpea variety 10 contains 23.6 % of crude protein content (Nurmomade et al., 2024). Starch digestibility improved with the germination process in pearl millet (Archana et al., 2001), in cowpeas (Nnanna and Phillips, 1990) and in composite porridges based on cereals and legumes (Gahlawat and Sehgal, 1994). Additionally, using germinated and fermented cereal and legumes as ingredients enhances starch and protein digestibility, increases mineral absorption and reduces resistant starch (Abbas and Ahmad, 2018; Oghbaei and Prakash, 2016).

Traditional processing methods, such as germination and fermentation, can alter the characteristics of these grains in beneficial ways. These pre-treatments are effective in reducing anti-nutritional factors like phytic acid that may limit the bioavailability of minerals and impair protein digestion (Adebo et al., 2022; Chaves-López et al., 2020; Griffith and Castell-Perez, 1998; Hassan et al., 2020). In addition, germination and fermentation improve several sensory attributes of the final product. Specifically, they help reduce bitterness, enhance natural sweetness and improve visual appearance, often making the product lighter (Garrido-Galand et al., 2021; Lemmens et al., 2019; Verni et al., 2022). These pre-treatments also soften the seed and reduce cooking time, contributing to a better mouthfeel and palatability. For example, Togwa, a traditional non-alcoholic drink made from maize and germinated finger millet flour, has a natural sweet taste without the need for adding sugar (Kitabatake et al., 2003). Lemmens et al. (2019) also reported that sprouted seeds improved consumer perceptions of flavour and overall taste, highlighting the positive sensory impact of germination.

Therefore, understanding the caregivers' liking and acceptability of composite porridges made from pearl millet and cowpea is essential for successfully introducing these products into Mozambican communities, particularly to address the nutritional needs of children. This study explores the perceived liking of a newly developed composite porridge formulated using fermented and germinated pearl millet and cowpea among caregivers of children under the age of five, conducted in Cabo Delgado Province, Mozambique. The findings of this study propose sustainable food solutions that reduce reliance on imported or industrial products by using locally available, climate-resilient crops such as pearl millet and cowpea. Moreover, the results can help shift cultural perspectives on food choices and encourage stakeholders and policymakers to promote and disseminate these composite porridges as a practical strategy to reduce undernutrition in Mozambique.

2. Materials and methods

2.1. Production of ingredients

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) variety changara and cowpea (*Vigna unguiculata* (L.) Walp) variety 10 were obtained from the Mozambican Agricultural Research Institute in Montepuez, Cabo Delgado. The samples were sorted and cleaned to remove damaged grains, stones, and extraneous material. The seeds were prepared following the method described by Nurmomade et al. (2024) with slight modifications using natural conditions.

For soaking pre-treatment, the seeds were soaked in tap water for 10 min in a 1:3 (w/w) ratio for pearl millet and 1:4 (w/w) for cowpea, then sun-dried for 24 h. For germination, the seeds were soaked in tap water for 24 h in a 1:3 (w/w) ratio for pearl millet and 1:4 (w/w) for cowpea and then allowed to germinate for 48 h at room temperature (25 ± 2 °C). Then, the seeds were washed and sun-dried for 24 h, and the dried rootlets were removed by rubbing between the hands before milling. For fermentation, the seeds were soaked in tap water at room temperature (25 ± 2 °C), in a 1:3 (w/w) ratio for pearl millet and 1:4 (w/w) for cowpea, and allowed to ferment for 72 h. Then, the seeds were washed and sun-dried for 24 h.

After sun-drying, all seeds were milled following a traditional process typically followed in Mozambique, which consists of pre-milling seeds with a wooden pestle and mortar until the bran was considered satisfactorily detached then the bran was winnowed from the endosperm grits using a winnowing basket and further milling with a wooden pestle and mortar to obtain the flour. Flour was stored in a polyethylene plastic bag at room temperature (25 ± 2 °C) until cooking the porridge for sensory evaluation.

2.2. Porridge formulation

The formulations used in this study were based on the proportions presented in Table 1. The composite porridges were formulated in ratios of 60 % cereal to 40 % legume, according to Griffith et al. (1998).

2.3. Pasting properties

Pasting properties were determined by a rapid visco analyser (RVA) (Newport Scientific, Australia), using 3.8 g of flour dispersed in 25 mL deionised water in an aluminium canister, mimicking the traditional way of preparing porridge. The samples were heated from 50 °C to a maximum temperature of 95 °C and held at 95 °C for 2.5 min before cooling to 50 °C, using the common Standard 1 method (Std1). Pasting temperature, peak viscosity, peak time, breakdown, trough, setback and final viscosity were recorded.

2.4. Colour measurements

The colour measurements were done to the porridges made with RVA in the laboratory at Uppsala, using a Konica Minolta spectrophotometer CM-600d (Konica Minolta, inc., Japan). The instrument was calibrated using a supplied white calibration plate. The samples were uniformly packed in a transparent Petri plate (Fig. 1). The instrument was placed on the plate with lid on, and three exposures at different places were conducted. The colour parameters were expressed as L*, a* and b* values. The L* values stand for whiteness to darkness. The chromatic portion was analysed by a* (+) redness and a* (−) greenness, b* (+) yellowness and b* (−) blueness.

2.5. Porridge preparation in Mozambique

Cooked porridges were prepared in a 13 % (w/v) concentration (208 g of flour mixed with approximately 1400 ml of tap water). An initial flour paste was made by mixing 208 g of flour and half of the water at room temperature. The paste was added to the other half of the boiled water and mixed well. Flour-water slurries were cooked in a traditional way, using coal to keep boiling the porridge (Fig. 2). Cooking was done within 15 min; sometimes, an additional 5 min was necessary to make sure that the porridge was cooked when the temperature of cooking was affected due to the coal type. Stirring was necessary throughout the cooking of the porridge to avoid lump formation. Cooked porridge was served at the appropriate temperature for consumption, between 40 and 50 °C and sugar was added just before the sensory test (1.5 g of sugar to

Table 1
Experimental design of different formulations.

CODE		Pearl Millet				Cowpea			
		Treatments (%)				Treatments (%)			
1	**SM**	Soaked	100	–		–		–	
2	**FMFP**	Fermented	60	–		Fermented	40	–	
3	**FGMFP**	Fermented	55	Germinated	5	Fermented	40	–	
4	**FMFGP**	Fermented	60	–		Fermented	35	Germinated	5

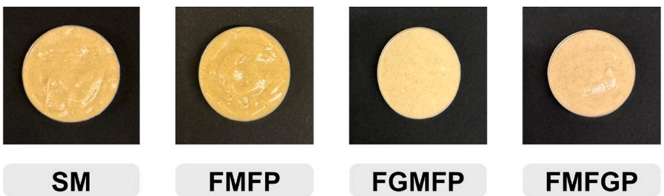

Fig. 1. Porridges on a Petri plate.
SM - 100 % soaked pearl millet (control); **FMFP** - 60 % fermented pearl millet + 40 % fermented cowpea; **FGMFP** - 55 % fermented pearl millet + 5 % germinated pearl millet + 40 % fermented cowpea; and **FMFGP** - 60 % fermented pearl millet + 35 % fermented cowpea +5 % germinated cowpea.

Fig. 2. The traditional way to cook porridge using coal.

40 g of porridge).

2.6. Sensory analysis of the porridges

Sensory evaluation was performed in accordance with the rules of the Ethics Committee of the Medicine Faculty and Central Hospital of Maputo, in Mozambique, approved under the number CIBS FM&HCM/15/2023 on July 29, 2024.

A 9-point hedonic scale (1 = dislike extremely to 9 = like extremely) was used to assess the sensory attributes of the composite porridges. Samples were evaluated by adult caregivers in Cabo Delgado Province, in Mozambique. The sensory evaluation was conducted in three different locations in Cabo Delgado. There were 64 caregivers in Copuito, 66 in Pulupu, and 77 in Nanguasse. Inclusion criteria for participation consisted of being over 18 years old, being the mother of children aged five or under, confirming prior experience consuming pearl, to ensure general familiarity with the seed, and wishing to participate in the study without being paid. The participants were recruited and selected with the help of leaders in each location.

The sensory evaluation test took place outdoors, and the participants were sitting on the floor in a shady place according to available conditions in each location (Fig. 3). To avoid allergic reactions and ambiguities, participants were explained about the process and informed in advance about the composition of the porridges. Then, the consent form to sign was given before proceeding with the sensory evaluation.

Each participant received an evaluation form, a pen, a bottle of mineral water, and a plastic spoon for each sample (Fig. 4). The porridge samples (40 g/person) were randomly distributed in a transparent plastic cup. Each treatment sample was designated a random three-digit code, which appeared on the corresponding cup. One sample was tested per time to avoid misunderstanding. Given that most caregivers have limited literacy in Portuguese, all instructions were delivered in the local languages, Emakhuwa and Kimwani, by a trained community nutritionist. Participants were then assisted in rating the hedonic scale and instructed to avoid communication with each other during the sensory evaluation.

The sensory attributes (appearance, colour, aroma, and taste) were used to evaluate the samples. The caregivers analysed the appearance first, following the above order. At the end of the evaluation, participants were selected based on their willingness to provide feedback. In total, 55 participants from the three communities were selected and were asked further questions to clarify their evaluations. The face scale was included in the evaluation form (sensory evaluation form in the annexure) to help caregivers understand the explanation.

Porridges were served at an appropriate temperature for consumption, between 40 and 50 °C. According to Mouquet & Trèche (2001), the typical consumption temperature for porridges is 43 ± 2 °C. The participants were instructed to cleanse their palates by drinking mineral water between the samples.

Fig. 3. Open environment (outdoors) for sensory analysis.

Fig. 4. Caregivers' evaluating composite porridges.

2.7. Statistical analyses

Sensory data were analysed using the statistical software Minitab version 19.2. Two-way ANOVA was generated using the general linear model procedure with composite porridge, location and their interaction as factors. Tukey's pairwise comparison test was used to identify significant differences between group means, with a significance level set at a 95 % confidence level.

Pasting properties and colour measurements were analysed using the statistical software Minitab version 19.2, and one-way ANOVA was performed. For porridge differences, Tukey's pairwise comparison test was used.

Principal component analysis (PCA) was performed using the software SIMCA 17 (Sartorius Stedim Data Analytics AB) to visualize the liking of porridges in different locations in Mozambique. The perceived liking of these composite porridges in different locations was analysed in relation to their pasting properties and colour measurements obtained in the laboratory in Uppsala.

A word cloud was generated using the free online application WordClouds.com to assess the caregivers' opinions on composite porridges.

3. Results and discussion

3.1. Pasting properties

The pasting properties of composite porridges are illustrated in Fig. 5. Significant differences in final viscosity were observed between porridges. Final viscosity values indicate the ability of flour to form a viscous paste/gel after cooking and cooling. The final viscosity of composite porridge containing germinated pearl millet (FGMFP) decreased dramatically compared to soaked pearl millet porridge (SM). SM porridge exhibited the highest final viscosity value of approximately 4000 mPa s (Table 2), indicating a greater swelling capacity of the starch granules in soaked pearl millet. SM is a typically traditional cereal porridge known for its high viscosity, which necessitates dilution with water to reduce thickness, ultimately resulting in a porridge with lower energy density. Similar results were reported (Kikafunda et al., 1997; Oladiran and Emmambux, 2022).

In contrast, the final viscosity of FGMFP porridge was recorded at approximately 600 mPa s (Table 2). Utilizing germinated flour to prepare porridges is a good strategy to liquefy thick porridges. This is due to the breakdown of starch granules by α-amylase, which is activated during the germination process. A study by Yenasew and Urga (2023) demonstrated that adding a small amount (5 %) of germinated millet flour as an ingredient reduces viscosity to a semi-liquid consistency. Consequently, the energy density of the porridge can be increased by

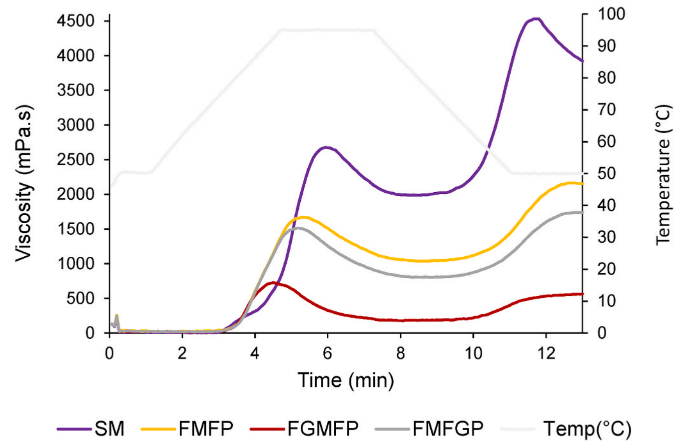

Fig. 5. Pasting properties of composite porridges
SM - 100 % soaked pearl millet (control); **FMFP** - 60 % fermented pearl millet + 40 % fermented cowpea; **FGMFP** - 55 % fermented pearl millet + 5 % germinated pearl millet + 40 % fermented cowpea; and **FMFGP** - 60 % fermented pearl millet + 35 % fermented cowpea +5 % germinated cowpea.

properly combining ingredients and adjusting the type of flour used to achieve the desired viscosity (Kikafunda et al., 1997). Brandtzaeg et al. (1981) and Oladiran and Emmambux (2022) have reported similar results, clearly indicating that germination has a high potential for increasing energy density.

When germinated cowpea flour was added to the composite porridge (FMFGP), the reduction in viscosity was less pronounced than with germinated pearl millet flour (Fig. 5). The final viscosity of the FMFGP porridge was approximately 1800 mPa s (Table 2). Nurmomade et al. (2024) noted a lower breakdown of starch granules in germinated cowpea flour compared to germinated pearl millet flour.

Porridge viscosity is a critical parameter in the formulation of composite foods for children, as it directly affects swallowing, nutrient intake, and satiety. According to Thaoge et al. (2003) and Oladiran and Emmambux (2022), the recommended apparent viscosity for children's porridges, measured at 54 rpm, ranges between 1000 and 3000 mPa s to ensure adequate consistency. In this study, the final viscosity of the composite porridge measured using Rapid visco analyser (RVA) was 2163 mPa s for FMFP and 1749 mPa s for FMFGP (Table 2), both of which fell within the recommended viscosity range (Fig. 5).

It is important to note that viscosity measurements can vary significantly depending on the measurement method and instrument, for instance, laboratory or field, or industrial settings (Mouquet and Trèche, 2001). As reported by Ojijo and Shimoni (2004), porridge viscosity is a complex characteristic influenced by several factors, including shear rate, temperature, and cooking duration. Moreover, the sensory perception of viscosity can differ based on cultural preferences and food habits, which may influence caregiver acceptance.

Several researchers working with traditional porridges in developing countries, such as those in Africa, have reported practical methods at the household level to reduce high viscosity while increasing energy density (Makame et al., 2020; Moriconi et al., 2023; Oladiran and Emmambux, 2022). Viscosity is a crucial factor that can significantly influence both the quantity of food a child can consume and their overall energy intake. Porridges are best served to children while warm, as cold porridge tends to thicken (Mouquet and Trèche, 2001).

3.2. Colour measurement of composite porridges

Results of lightness (L*), green/red (a*) and yellow/blue (b*) of composite porridges are presented in Table 3. The values of lightness (L*) ranged from 49.8 to 56.0, statistically significant. The darkest porridge was SM, with the lowest (L*) value, and the lightest porridge

Table 2
Pasting properties of composite porridges.

Composite porridge	Peak Viscosity (mPa.s)	Trough Viscosity (mPa.s)	Breakdown Viscosity (mPa.s)	Final Viscosity (mPa.s)	Setback Viscosity (mPa.s)	Peak Time (min)	Pasting Temp. (°C)
SM	2637^{a}	1968^{a}	670^{a}	3828^{a}	1860^{a}	5.9^{a}	77.5^{b}
FMFP	1685^{b}	1037^{b}	648^{a}	2163^{b}	1126^{b}	5.3^{b}	79.1^{a}
FGMFP	719^{d}	168^{d}	552^{b}	545^{d}	377^{c}	4.5^{d}	79.1^{a}
FMFGP	1507^{c}	790^{c}	718^{a}	1749^{c}	960^{b}	5.2^{c}	80.0^{a}

Pasting properties values are the mean of duplicates. Different letters within columns indicate significant differences $p \leq 0.05$ in Tukey's pair-wise comparison.
SM - 100 % soaked pearl millet (control); **FMFP** - 60 % fermented pearl millet + 40 % fermented cowpea; **FGMFP** - 55 % fermented pearl millet + 5 % germinated pearl millet + 40 % fermented cowpea; and **FMFGP** - 60 % fermented pearl millet + 35 % fermented cowpea +5 % germinated cowpea.

Table 3
Colour measurements of composite porridges.

Composite porridge	L*	a*	b*
SM	49.8^{c}±0.1	0.7^{b} ± 0.1	11.4^{a}±0.2
FMFP	54.5^{b} ± 0.1	1.2^{a}±0.03	10.2^{b} ± 0.2
FGMFP	56.0^{a}±0.1	1.1^{a}±0.00	10.2^{b} ± 0.1
FMFGP	54.5^{b} ± 0.2	1.1^{a}±0.04	10.0^{b} ± 0.2

Values shown are mean ± standard deviation of duplicates. Different letters within columns indicate significant differences $p \leq 0.05$ in Tukey's pair-wise comparison of colour measurements.
SM - 100 % soaked pearl millet (control); **FMFP** - 60 % fermented pearl millet + 40 % fermented cowpea; **FGMFP** - 55 % fermented pearl millet + 5 % germinated pearl millet + 40 % fermented cowpea; and **FMFGP** - 60 % fermented pearl millet + 35 % fermented cowpea +5 % germinated cowpea.

was FGMFP, containing germinated pearl millet, with the highest L* value. The addition of germinated pearl millet might have influenced the lightness. Similarly, Nefale & Mashau (2018) reported that the lightness increased when finger millet was germinated for 72 h in comparison with ungerminated finger millet.

3.3. Sensory evaluation

The sensory evaluation showed significant variations in the caregivers' liking for the sensory attributes of the composite porridge, as detailed in Table 4. The traditional porridge, described as SM, is made exclusively from 100 % soaked pearl millet and is well-known in Copuito, Pulupu and Nanguasse. Interestingly, there were no significant differences in liking between SM and one of the newly developed composite porridges, FMFGP, which consists of 60 % fermented pearl millet, 35 % fermented cowpea, and 5 % germinated cowpea. Both porridges were the most liked across all sensory attributes, appearance, colour, aroma, and taste in all locations, as represented in Fig. 6, word cloud. A word cloud presents caregivers feedback about their opinions,

Fig. 6. Word cloud of responses of face-to-face interviews about caregivers opinions on the composite porridge. The largest font size represents words that were mentioned at least 6 times, and the smallest font size represents words that were mentioned at least one time.

along with suggestions for improvement. The majority of caregivers expressed familiarity with soaked pearl millet porridge (SM) taste, as it is their traditional porridge, and they also expressed a liking for the taste of FMFGP. As shown in Table 4, no statistically significant difference was observed between these two porridges in terms of taste.

Table 4
Caregiver's evaluation for composite porridges in three different locations.

Composite porridges	Location	Appearance	Colour	Aroma	Taste	Overall acceptability
SM	Copuito	8.1^{a}±1.3	7.6^{ab} ± 1.5	7.4^{abc}±1.8	8.1^{a}±1.0	7.8^{ab} ± 1.0
FMFP	Copuito	5.9^{bc}±2.6	5.8^{de} ± 2.5	6.2^{de} ± 2.4	5.9^{de} ± 2.7	6.0^{c}±2.0
FGMFP	Copuito	5.6^{cd} ± 2.6	5.7^{e}±2.7	5.1^{f}±2.7	5.4^{e}±2.9	5.5^{c}±2.3
FMFGP	Copuito	7.5^{a}±1.8	6.9^{bcd} ± 2.1	7.0^{bcd} ± 2.0	7.0^{abcd}±2.4	7.1^{b} ± 1.6
SM	Pulupu	7.6^{a}±1.3	8.0^{a}±1.1	8.0^{ab} ± 1.1	8.1^{a}±1.2	7.9^{ab} ± 0.6
FMFP	Pulupu	4.3^{d} ± 2.9	5.9^{de} ± 2.5	5.7^{ef}±2.5	6.6^{bcde} ± 2.9	5·3^{c}±2.1
FGMFP	Pulupu	4.8^{cd} ± 3.2	6.3^{cde} ± 1.8	6.7^{cde} ± 1.8	6.7^{b} ± 2.2	6.0^{c}±1.6
FMFGP	Pulupu	7.1^{a}±2.1	7.1^{abc}±1.8	7.6^{abc}±1.6	7.5^{abc}±2.1	7.3^{ab} ± 1.5
SM	Nanguasse	8.0^{a}±1.6	7.9^{a}±1.6	8.0^{ab} ± 1.7	8.1^{a}±1.6	8.0^{a}±1.3
FMFP	Nanguasse	7.0^{ab} ± 2.2	7.7^{ab} ± 1.4	7.5^{abc}±1.7	7.6^{abc}±1.9	7.4^{ab} ± 1.5
FGMFP	Nanguasse	7.0^{ab} ± 2.5	7.9^{a}±1.0	7.9^{ab} ± 1.3	6.8^{cd} ± 2.7	7.4^{ab} ± 1.5
FMFGP	Nanguasse	8.1^{a}±1.2	8.1^{a}±1.2	8.1^{a}±1.3	8.0^{ab} ± 1.4	8.1^{a}±1.0

Values shown are the mean of sensory ±standard deviation. Different letters within columns indicate significant differences $p \leq 0.05$ in Tukey's pair-wise comparison of composite porridges and locations.
SM - 100 % soaked pearl millet (control); **FMFP** - 60 % fermented pearl millet + 40 % fermented cowpea; **FGMFP** - 55 % fermented pearl millet + 5 % germinated pearl millet + 40 % fermented cowpea; and **FMFGP** - 60 % fermented pearl millet + 35 % fermented cowpea +5 % germinated cowpea.

In contrast, the porridges that were least liked were FMFP, which contained 60 % fermented pearl millet and 40 % fermented cowpea, and FGMFP, which consists of 55 % fermented pearl millet, 5 % germinated pearl millet, and 40 % fermented cowpea. Caregivers observed that these two porridges had a thin viscosity, which influenced their lower liking. However, some caregivers mentioned that they like a thin porridge to feed their children. Although there were several comments concerned with viscosity, all porridges were accepted, as shown in Fig. 6. Common words used in caregivers' answers are presented in a word cloud, Fig. 6. The largest font size represents words that were mentioned 6 times, and the smallest font size represents words that were mentioned only one time. Composite porridge, FGMFP, had the lowest viscosity of around 600 mPa s. In comparison, FMFGP measured about 1800 mPa s and FMFP about 2200 mPa s. The highest final viscosity of porridge was SM, which was approximately 4000 mPa s.

Using germinated and fermented flour as ingredient played a crucial role in reducing the viscosity of the porridges. The enzymes present in germinated flour break down the starch granules, leading to less swelling and lower water-binding capacities (Kaur and Gill, 2020). Nurmomade et al. (2024) reported that germinated pearl millet and cowpea flour do not swell as much compared to soaked flour, resulting in low viscosity. This characteristic allows for adding more flour to the porridge, producing a high-energy-density food (Alexander, 1983; Oladiran and Emmambux, 2022; Griffith et al., 1998).

The composite porridge FGMFP had the lowest viscosity among the tested porridges (Fig. 5). Although it presents an opportunity to increase energy density, caregivers liked other options due to the intense taste and aroma of beans. The higher amount of fermented cowpea (40 %) may have contributed to its more pronounced taste and aroma of beans. Chanadang and Chambers (2019) found similar results, noting that as the quantity of legumes in formulations increases, the beany characteristics become more pronounced.

It is important to note that although the intense aroma and taste of beans were present in all three newly developed composite porridges in this study, caregivers generally liked them. Roland et al. (2017) reported that off-flavour compounds in legumes are primarily derived from the oxidation of unsaturated fatty acids, and many of these characteristics are often linked to the action of the lipoxygenase enzyme.

Regular exposure to these composite porridges made from cereals and legumes may be necessary to enhance their acceptance and potentially shift cultural choices in Mozambique. Repeated exposure to novel extruded fortified blended foods increased children's acceptability of the products in Tanzania (Chanadang and Chambers IV, 2020). Moreover, they suggested that children may increase their perceived liking of some food products after repeated exposure and may increase their liking for some food products more than for others over an extended time period.

All composite porridges in this study were served with sugar, a common practice in Mozambique to enhance the palatability of porridges. Some caregivers mentioned that composite porridge FGMFP was very sweet, even though the same amount of sugar was added to all samples. The sweetness perceived in FGMFP may be attributed to the presence of dextrin, maltose and oligosaccharide in germinated flour. Using germinated flour to prepare porridge can be a good strategy to avoid adding sugar to the composite porridge for children. According to Lineback and Ponpipom (1977) and Yang et al. (2021), during germination, starch is broken down by α-amylase, the principal enzyme activated during germination, resulting in dextrin, maltose and oligosaccharide. A traditional non-alcoholic drink, Togwa, made with maize and germinated finger millet flour, has a sweet taste without adding sugar, as reported by Kitabatake et al. (2003).

3.4. Principal component analysis

The liking of four sensory attributes (appearance, colour, aroma, and taste) was analysed using principal component analysis (PCA) across three different locations in the northern region of Mozambique, along with pasting properties and colour measurements performed in the laboratory in Uppsala. PCA helped to visualize the differences in porridge liking in Copuito, Pulupu and Nanguasse (Fig. 7). The first Principal Component (PC1) accounted for 65.6 % of the variation and effectively differentiated the samples, while the second Principal Component (PC2) explained 20.3 % of the variation.

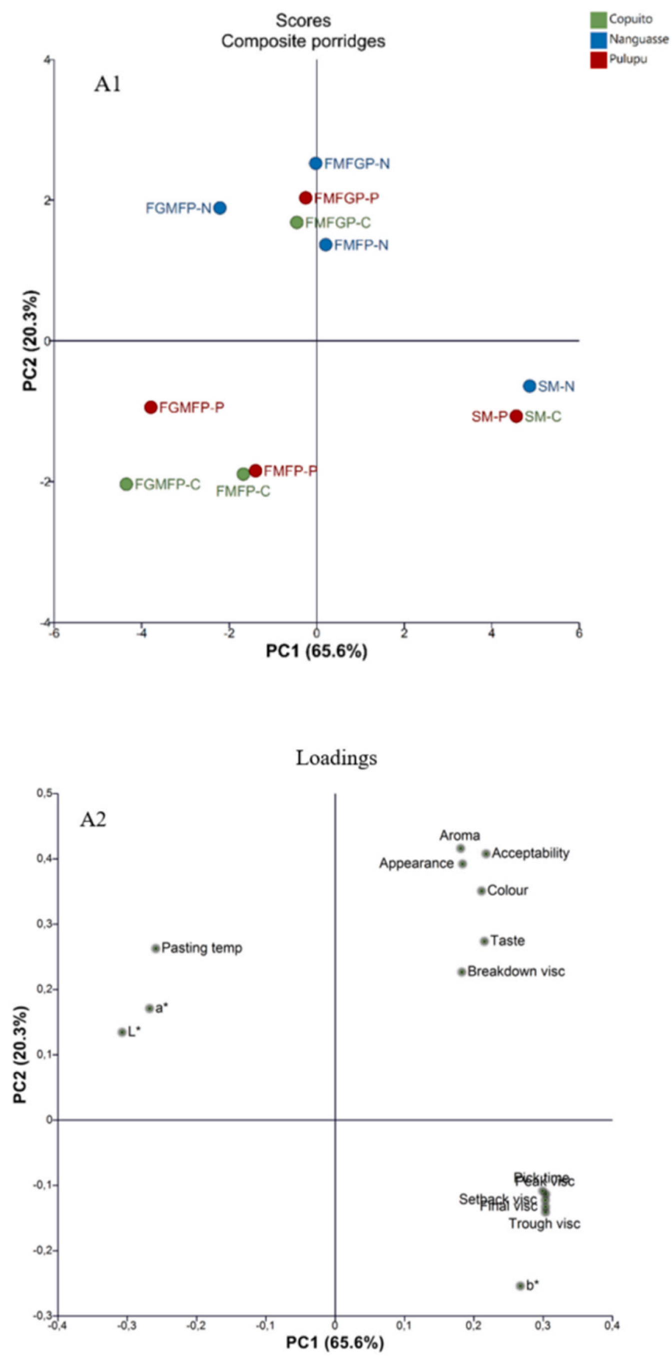

Fig. 7. Principal component analysis (PCA) plots. (A1) Score plot of composite porridges in three locations: C – Copuito (green), N – Nanguasse (blue), and P – Pulupu (red). (A2) Loading plot with sensory attributes, pasting properties and colour measurements.
Composite porridges: SM - 100 % soaked pearl millet (control); **FMFP** - 60 % fermented pearl millet + 40 % fermented cowpea; **FGMFP** - 55 % fermented pearl millet + 5 % germinated pearl millet + 40 % fermented cowpea; and **FMFGP** - 60 % fermented pearl millet + 35 % fermented cowpea +5 % germinated cowpea.

Among the four porridges evaluated, the traditional porridge made with soaked pearl millet (SM) was liked across all sensory attributes in all three locations, which was expected due to its familiar appearance, taste and sociocultural relation. The PCA results indicated that SM and FMFGP were grouped on the positive side of PC1, as both were characterised as "good porridge," the caregivers expressed a strong liking for them, and both porridges, SM and FMFGP showed no statistically significant differences in all sensory attributes such as appearance, colour, aroma, and taste.

All composite porridges were liked for their appearance, colour, aroma, and taste in all locations. However, the combinations of FMFP (60 % fermented pearl millet and 40 % fermented cowpea) and FGMFP (55 % fermented pearl millet, 5 % germinated pearl millet, and 40 % fermented cowpea) were the least liked in Copuito and Pulupu and were grouped on the negative side of PC1. It is also important to note that in Nanguasse, all porridges were liked very much since people consume more pearl millet than in the other two locations, which makes it easier for them to like all porridges because it is part of their cultural practices.

4. Conclusion

The results of this study demonstrate that all composite porridges were liked in all locations. The newly composite porridge most liked was FMFGP (60 % fermented pearl millet + 35 % fermented cowpea +5 % germinated cowpea).

The addition of germinated pearl millet affected the appearance of the composite porridge (FGMFP), resulting in a thinner porridge. This porridge has the potential to be enhanced by adding solid content to adjust the viscosity, nutrient and energy density.

The distinct aroma and taste of beans were due to the presence of cowpea in the composite porridges, which caregivers were not familiar with, affecting their liking. Nevertheless, the quantity can be adjusted according to participants liking.

Composite porridges FGMFP and FMFGP have the potential to be successfully introduced in communities and used to improve children's nutritional status to address malnutrition challenges in Mozambique.

Study limitations

This study had certain limitations. The composite porridge formulations were tested with caregivers of children aged five or under, although the intended group for the porridges is children, particularly those weaning and pre-school aged. In Mozambique, mothers usually serve as the primary caregivers and cooks for their children. Additionally, a second limitation was ensuring a consistent cooking temperature, as we used a traditional way to cook porridges in the communities using coal, as shown in Fig. 2.

CRediT authorship contribution statement

Sunera Nurmomade: Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Maria Eduardo:** Writing – review & editing, Supervision, Conceptualization. **Santanu Basu:** Writing – review & editing, Supervision, Conceptualization. **Irene de Carvalho:** Writing – review & editing, Visualization, Supervision, Conceptualization. **Roger Andersson:** Writing – review & editing, Validation, Supervision, Conceptualization. **Karin Wendin:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Conceptualization.

Implications for gastronomy

The findings of this study provide valuable insights for the gastronomy sector, presenting an opportunity to incorporate pearl millet and cowpea into a variety of recipes, encouraging innovation while preserving ancient culinary practices through fermented and germinated seeds. Caregivers responded positively to the newly developed composite porridge made from fermented and germinated pearl millet and cowpea, highlighting the potential of these nutrient-dense, climate-resilient crops to support health and address malnutrition. This effort not only seeks to maintain cultural identity but also aims to enhance the sensory attributes and inspire chefs, food entrepreneurs, and product developers worldwide to explore new applications of fermented and germinated seeds, encouraging the development of sustainable, culturally relevant food products.

Funding

This work was supported by grants from the Swedish International Development Cooperation Agency (Sida), subprogram 1.2.1 (Sida Decision No: 2017/11862).

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgements

The authors would like to thank the mothers who participated in the test and the community leaders who helped us spread the information and encouraged the participants. We would also like to thank District Services for the Economic Activities (SDAE) in Balama, Namuno, and Mecufi, the Provincial Directorate of Agriculture and Fisheries, and the Provincial Directorate of Health in Cabo-Delgado, specifically (NIOP), Eng°. Rogerio Chiulele, Eng°. Joaquim Américo Mutaliano and Eng°. Walter Saibo, for providing pearl millet and cowpea seeds, producing and harvesting.

Data availability

Data will be made available on request.

References

Abbas, Y., Ahmad, A., 2018. Impact of processing on nutritional and antinutritional factors of legumes: a review. Annals: Food Sci. Technol. 19 (2).

Adebo, J.A., Njobeh, P.B., Gbashi, S., Oyedeji, A.B., Ogundele, O.M., Oyeyinka, S.A., Adebo, O.A., 2022. Fermentation of cereals and legumes: impact on nutritional constituents and nutrient bioavailability. Fermentation 8 (2), 63. https://www.mdpi.com/2311-5637/8/2/63.

Alexander, C.M., 1983. Preparation of weaning foods with high nutrient density using flour of germinating cereals. Food Nutr. Bull. 5 (2), 10–14.

Archana, Sehgal, S., Kawatra, A., 2001. In vitro protein and starch digestibility of pearl millet (Pennisetum gluacum L.) as affected by processing techniques. Food Nahrung 45 (1), 25–27. https://doi.org/10.1002/1521-3803(20010101)45:1<25::AID-FOOD25>3.0.CO;2-W.

Brandtzaeg, B., Malleshi, N., Svanberg, U., Desikachar, H., Mellander, O., 1981. Dietary bulk as a limiting factor for nutrient intake-with special reference to the feeding of pre-school children. HI. Studies of malted flour from ragi, sorghum and green gram. Journal of Tropical Pediatrics 184-189 ((4). 1465-3664 0142-6338), 27.

Chanadang, S., Chambers, E., 2019. Determination of the sensory characteristics of traditional and novel fortified blended foods used in supplementary feeding programs [Article]. Foods 8 (7), 261. https://doi.org/10.3390/foods8070261.

Chanadang, S., Chambers IV, E., 2020. Understanding children's acceptability after repeated exposure and household-level behaviors for novel extruded fortified blended foods. J. Sensory Stud. 35 (4), e12530. https://doi.org/10.1111/joss.12530.

Chaves-López, C., Rossi, C., Maggio, F., Paparella, A., Serio, A., 2020. Changes occurring in spontaneous maize fermentation: an overview. Fermentation 6 (1), 36. https://doi.org/10.3390/fermentation6010036.

Gahlawat, P., Sehgal, S., 1994. In vitro starch and protein digestibility and iron availability in weaning foods as affected by processing methods. Plant Foods Hum. Nutr. 45 (2), 165–173. https://doi.org/10.1007/bf01088474.

Garrido-Galand, S., Asensio-Grau, A., Calvo-Lerma, J., Heredia, A., Andrés, A., 2021. The potential of fermentation on nutritional and technological improvement of cereal and legume flours: a review. Food Res. Int. 145, 110398. https://doi.org/10.1016/j.foodres.2021.110398.

Griffith, L.D., Castell-Perez, M.E., Griffith, M.E., 1998. Effects of blend and processing method on the nutritional quality of weaning foods made from select cereals and legumes. Cereal Chemistry Journal 75 (1), 105–112. https://doi.org/10.1094/CCHEM.1998.75.1.105.

Griffith, L.D., Castell-Perez, M.E., 1998. Effects of roasting and malting on physicochemical properties of select cereals and legumes. Cereal Chem. 75 (6), 780–784. https://doi.org/10.1094/CCHEM.1998.75.6.780.

Hassan, S., Hussain, M.B., Waheed, M., Ahmad, K., Kassymov, S., Shariati, M.A., Akram, M., Mishra, A.P., Egbuna, C., 2020. Effect of germination processing on bioactive compounds of cereals and legumes. In: Egbuna, C., Dable Tupas, G. (Eds.), Functional Foods and Nutraceuticals: Bioactive Components, Formulations and Innovations. Springer International Publishing, pp. 283–306. https://doi.org/10.1007/978-3-030-42319-3_16.

Instituto Nacional de Estatística (INE) e ICF, 2023. Inquérito Demográfico e de Saúde em Moçambique 2022-23. Maputo, Moçambique e Rockville, Maryland, EUA: INE e ICF.

Kaur, H., Gill, B.S., 2020. Comparative evaluation of physicochemical, nutritional and molecular interactions of flours from different cereals as affected by germination duration. J. Food Meas. Char. 14 (3), 1147–1157. https://doi.org/10.1007/s11694-019-00364-5.

Kikafunda, J.K., Walker, A.F., Abeyasekera, S., 1997. Optimising viscosity and energy density of maize porridges for child weaning in developing countries. Int. J. Food Sci. Nutr. 48 (6), 401–409. https://doi.org/10.3109/09637489709028589.

Kitabatake, N., Gimbi, D.M., Oi, Y., 2003. Traditional non-alcoholic beverage, Togwa, in East Africa, produced from maize flour and germinated finger millet. Int. J. Food Sci. Nutr. 54 (6), 447–455. https://doi.org/10.1080/09637480120092053.

Lemmens, E., Moroni, A.V., Pagand, J., Heirbaut, P., Ritala, A., Karlen, Y., Lê, K.-A., Van den Broeck, H.C., Brouns, F.J.P.H., De Brier, N., Delcour, J.A., 2019. Impact of cereal seed sprouting on its nutritional and technological properties: a critical review. Compr. Rev. Food Sci. Food Saf. 18 (1), 305–328. https://doi.org/10.1111/1541-4337.12414.

Lineback, D.R., Ponpipom, S., 1977. Effects of germination of wheat, oats, and Pearl Millet on alpha-amylase activity and starch degradation. Starch - Stärke 29 (2), 52–60. https://doi.org/10.1002/star.19770290205.

Makame, J., De Kock, H., Emmambux, N.M., 2020. Nutrient density of common African indigenous/local complementary porridge samples. Lebensm. Wiss. Technol. 133, 109978. https://doi.org/10.1016/j.lwt.2020.109978.

Moriconi, L., Vittadini, E., Linnemann, A.R., Fogliano, V., Ngadze, R.T., 2023. Designing sustainable weaning foods for developing countries: not only a matter of nutrients. Food Funct. 14 (20), 9194–9203. https://doi.org/10.1039/d3fo02832a.

Mouquet, C., Trèche, S., 2001. Viscosity of gruels for infants: a comparison of measurement procedures. Int. J. Food Sci. Nutr. 52 (5), 389–400. https://doi.org/10.1080/09637480120078276.

Nefale, F.E., Mashau, M.E., 2018. Effect of germination period on the physicochemical, functional and sensory properties of Finger Millet Flour and porridge. Asian Journal of Appl. Sci. 6 (5). https://doi.org/10.24203/ajas.v6i5.5466.

Nnanna, I.A., Phillips, R.D., 1990. Protein and starch digestibility and flatulence potential of germinated cowpeas (Vigna unguiculata). J. Food Sci. 55 (1), 151–153. https://doi.org/10.1111/j.1365-2621.1990.tb06039.x.

Nout, M.J.R., Ngoddy, P.O., 1997. Technological aspects of preparing affordable fermented complementary foods. Food Control 8 (5–6), 279–287. https://doi.org/10.1016/s0956-7135(97)00001-7.

Nurmomade, S., Basu, S., de Carvalho, I., Eduardo, M., Andersson, R., 2024. Effect of pre-treatment on physicochemical, microstructural and pasting properties of pearl millet and cowpea. Lebensm. Wiss. Technol. 198, 115951.

Oghbaei, M., Prakash, J., 2016. Effect of primary processing of cereals and legumes on its nutritional quality: a comprehensive review. Cogent Food Agric. 2 (1), 1136015. https://doi.org/10.1080/23311932.2015.1136015.

Ojijo, N.K.O., Shimoni, E., 2004. Rheological properties of fermented finger millet (Eleucine coracana) thin porridge. Carbohydr. Polym. 56 (2), 235–242. https://doi.org/10.1016/j.carbpol.2004.02.007.

Oladiran, D.A., Emmambux, N.M., 2022. Locally available African complementary foods: nutritional limitations and processing technologies to improve nutritional Quality—A review. Food Rev. Int. 38 (5), 1033–1063. https://doi.org/10.1080/87559129.2020.1762640.

Onofiok, N.O., Nnanyelugo, D.O., 1998. Weaning foods in West Africa: nutritional problems and possible solutions. Food Nutr. Bull. 19 (1), 27–33. https://doi.org/10.1177/156482659801900105.

Roland, W.S.U., Pouvreau, L., Curran, J., van de Velde, F., de Kok, P.M.T., 2017. Flavor aspects of pulse ingredients. Cereal Chem. 94 (1), 58–65. https://doi.org/10.1094/CCHEM-06-16-0161-FI.

Saaka, M., Saapiire, F.N., Dogoli, R.N., 2021. Independent and joint contribution of inappropriate complementary feeding and poor water, sanitation and hygiene (WASH) practices to stunted child growth. J. Nutr. Sci. 10, e109. https://doi.org/10.1017/jns.2021.103. Article e109.

Singhavanich, C., Jittinandana, S., Kriengsinyos, W., Dhanamitta, S., 1999. Improvement of dietary density by the use of germinated cereals and legumes. Food Nutr. Bull. 20 (2), 261–266. https://doi.org/10.1177/156482659902000213.

Thaoge, M.L., Adams, M.R., Sibara, M.M., Watson, T.G., Taylor, J.R.N., Goyvaerts, E.M., 2003. Production of improved infant porridges from pearl millet using a lactic acid fermentation step and addition of sorghum malt to reduce viscosity of porridges with high protein, energy and solids (30%) content. World J. Microbiol. Biotechnol. 19 (3), 305–310. https://doi.org/10.1023/A:1023614526667.

United Nations Children's Fund (UNICEF), 2023. World Health Organization (WHO), international bank for reconstruction and Development/The World Bank. Levels and Trends in Child Malnutrition: UNICEF/WHO/World Bank Group Joint Child Malnutrition Estimates: Key Findings of the 2023 Edition. UNICEF and WHO, New York. CC BY-NC-SA 3.0 IGO.

Verni, M., Pontonio, E., Montemurro, M., Giuseppe Rizzello, C., 2022. Fermentation as strategy for improving nutritional, functional, technological, and sensory properties of legumes. IntechOpen. https://doi.org/10.5772/intechopen.102523.

Yang, Q., Luo, Y., Wang, H., Li, J., Gao, X., Gao, J., Feng, B., 2021. Effects of germination on the physicochemical, nutritional and in vitro digestion characteristics of flours from waxy and nonwaxy proso millet, common buckwheat and pea. Innov. Food Sci. Emerg. Technol. 67, 102586. https://doi.org/10.1016/j.ifset.2020.102586.

Yenasew, A., Urga, K., 2023. Effect of the germination period on functional properties of finger millet flour and sensorial quality of porridge. Food Sci. Nutr. 11 (5), 2336–2343. https://doi.org/10.1002/fsn3.3240.