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Organoleptic drivers of caregiver-reported acceptability of locally formulated nutrient-dense products formulated from local ingredients for nutritional intervention in nodding syndrome in northern Uganda

Bonny Aloka^{1,2*}, Duncan Ongeng¹, Freda Oceng Amito³, Bernard Omech⁴ and Solomon Olum¹

Abstract

Background Nutritional approaches based on local food resources offer a potential intervention to address nodding syndrome (NS), a chronic neurological condition associated with undernutrition and micronutrient deficiency, with a 4.5% prevalence among children and adolescents in northern Uganda. Most interventions have been medical in nature, but diet influences the onset of such neurological diseases and their associated consequences. This study evaluated the organoleptic drivers of caregiver-reported acceptability of locally formulated nutrient-dense products formulated from local ingredients for nutritional intervention in nodding syndrome in northern Uganda as a potential nutritional intervention.

Methods The products were developed from two main energy sources: maize and sorghum, and included orange-fleshed sweet potato (OFSP), silver fish, soybean, iron-rich beans, and chia seeds. A total of 47 untrained panelists, who were caregivers of NS cases, evaluated different organoleptic properties of porridges from the two energy sources using a 5-point Hedonic scale to determine the level of preference for different formulations.

Results Overall acceptability increased with an increase in the proportion of cereals in the composite formulae. The formulation with 70% cereal scored highest, with products from the sorghum-based formula being preferred to those from the maize-based formula. Several food attributes and socio-demographic characteristics significantly influenced the acceptability of the products ($p < 0.05$).

For the maize-based formula, taste, thickness, and education level had a positive influence, whereas texture, age, and the number of children under two years had a negative influence on overall acceptability. For the sorghum-based formula, taste, texture, and age all had a positive influence on overall acceptability.

*Correspondence:
Bonny Aloka
alokabonny@gmail.com

Full list of author information is available at the end of the article



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Conclusions The results demonstrate that composite formulae with 70% cereals are highly acceptable and can be scaled up for consumption by NS having used the caregivers' acceptability as a proxy for NS patients. The study provides recommendations for the effective delivery of selected formulae in the study context.

Keywords Organoleptic driver, Nodding syndrome, Composite formulae, Northern Uganda

Introduction

Nodding syndrome (NS) is a poorly understood neurological disorder that affects children and adolescents aged 3–18 years [1, 2]. It is primarily prevalent in Sub-Saharan Africa (SSA) [3]. The prevalence rate in northern Uganda is 4.5% [4], particularly in districts affected by the Lord's Resistance Army (LRA) rebellion [5, 6]. The disease is characterised by atonic head-nodding seizures and is also associated with malnutrition and micronutrient deficiencies, such as vitamins B6 and D, as well as selenium [2, 7]. Malnutrition and chronic conditions like HIV/AIDS and NS have consistently been found to be associated with one another [8]. A previous study in Kitgum district, the NS hotspot in northern Uganda, found that vitamin B6 levels were lower among cases compared to controls [9]. Additionally, households where cases are common were found to consume less nutritious staple foods [10]. In situations where households were displaced to refugee camps, there was periodic food insecurity, leading affected households to resort to eating wild foods, as reported for the Wapagoro people of Tanzania and the Moru communities of South Sudan [11]. In other communities, such as the Dinka people in South Sudan who had access to milk, NS was less prevalent [11]. These findings support the link between NS and poor diet.

Northern Uganda, particularly the Acholi people, where this study was based, suffered from the Lord's Resistance Army (LRA) civil war, which lasted for over 20 years [12]. This conflict displaced nearly 1.8 million Acholi inhabitants to internally displaced people (IDP) camps, where emergency relief food was provided. During the war, seasonality in food production was a known determinant of food security and the nutritional status of most households [13]. The low quality of food interventions and seasonal food production led to high levels of food insecurity and poor dietary quality, a situation linked to the emergence of NS. To date, the Acholi sub-region and northern Uganda as a whole remain the most food-insecure parts of Uganda, and the only region with NS. The main interventions for NS cases in Sub-Saharan Africa have been medical, primarily through community-directed treatment with ivermectin (CDTI) [14, 15]. However, it is important to recognise the need to invest in nutrition alongside medical treatment, as proper response to medication is possible only if nutrition is adequate [16]. Despite this, common nutrition interventions have consisted of blanket distribution of supplementary foods such as beans and maize flour, which are

not nutrient-dense. In the rare instances when nutrient-dense foods, local food supplements, and multivitamins were provided, the NS cases showed significant improvement in nutritional status and reported less frequent nodding episodes [17]. This demonstrates the potential of nutritional intervention to improve the quality of life for NS cases. The nutritional intervention consisted of multivitamins (one tablet twice daily), folic acid (5 mg once daily), and high-energy food for nutritional rehabilitation [18]. The supply of multivitamins and nutritional supplements was not only expensive but also reached only those cases in rehabilitation centres, excluding the majority in the communities. This highlighted the need to develop locally produced nutrient-dense food composite formulae to benefit the many NS cases in the community.

Composite formulae made from local materials have been found effective in the African context [19], as well as in countries such as Indonesia [20] and Bangladesh [21]. The use of local food materials to develop food composite formulae has been shown to address issues of food insecurity, sustainability, and sovereignty [22]. Additionally, these products are more readily accepted by target groups, as they are made from familiar foods. Since northern Uganda is endowed with a variety of food items rich in different nutrients [23], nutrient-dense food composite formulae were developed from local foods to contribute to the nutritional needs of NS patients living in the region. However, it is generally known that food formulation results in products with variable properties compared to the individual ingredients [24]. The affected properties include sensory attributes such as colour, taste, texture, and aroma [25]. These properties essentially determine whether new formulations will be accepted or rejected by targeted consumers [26]. Furthermore, the introduction of a novel composite formulae to the community may evoke some initial aversion, which can be reduced when sensory analysis is conducted prior to introducing such foods. Despite its potential, there is limited evidence on the use of local food materials to address the nutritional needs of NS cases in Uganda and their acceptability. Therefore, while targeting staples and other locally known nutrient-dense foods for food formulation may hold promise for improving nutrition outcomes, it remains crucial to assess their acceptability and preference among the target beneficiaries [27]. The objective of this study was to determine the organoleptic properties and household characteristics that influence the acceptability of nutrient-dense food products

formulated from local ingredients for nutritional intervention in NS in northern Uganda. The sensory evaluation would inform necessary adjustments in formulation, selection, and recommendation of accepted formulations for efficacy trials and scaling up for widespread utilisation to achieve the desired nutritional outcomes.

Materials and methods

Study setting and participants

This study was conducted in Kitgum District in northern Uganda, located between longitude 32°E and 34°E, latitude 2°N and 4°N, about 440 km from Kampala, the capital of the country. This is one of the districts with a high prevalence rate of NS and which suffered greatly from over 20 years of LRA war [28]. Participants were mainly drawn from Labongo Akwang sub-county, which has a very high number of NS cases in the district, namely 1,305 cases per 100,000 [28].

Selected participants were untrained and had no prior knowledge of the preparation and composition of the composite formulae [29]. A total of 47 adults (18 years and above), primarily caregivers of NS patients, were purposively selected to evaluate the composite formulae. This selection was based on the understanding that these adults possess insights into the sensory preferences of individuals affected by NS, given their consistent

involvement in meal preparation. Additionally, since individuals with NS are a vulnerable population with cognitive and motor impairments, direct sensory evaluation was not ethically or practically feasible. Therefore, caregivers who are responsible for meal preparation and feeding, were engaged as proxy sensory panelists. Their hedonic ratings reflect observed patient responses and caregiver judgments of acceptability, which provide an indirect but valuable measure of the composite formulae acceptability. Only one participant was selected per household. Therefore, perspectives were gathered from 47 households caring for NS patients in Kitgum district. Previous research indicated that a sample size of 40–100 is adequate for conducting such consumer sensory evaluations [30]. An eligible participant was an adult caring for someone with NS disease in the household and willing to take part in the study. In addition, participants were those not suffering from flu, not allergic to any of the ingredients used in preparation, and not smokers, as this would affect their rating of taste perceptions.

Socio-demographic characteristics of participants

Socio-demographic characteristics of the caregivers who participated in the sensory evaluation were documented to provide context for interpreting acceptability outcomes. These characteristics are shown in Table 1. Nearly all participants were female (98%), with an average age of 48 years. The majority (75%) had attained primary education and were predominantly engaged in farming (98%). Approximately half were married (51%), and most identified as Catholic (54%). Their median monthly household income was low, at Ugandan Shillings (Ugx) 40,000 (approximately US\$10.8), despite supporting an average household size of nine members. Some sampled households had more than one person with nodding syndrome.

Level of inclusion of ingredients in the formulation

The locally available ingredients used to formulate the nutrient-dense composite formulae were selected primarily for their strong nutritional properties: orange-fleshed sweetpotato (*Ipomoea batatas*, OFSP), which contains β -carotene ranging from 277 $\mu\text{g/g}$ to 82,300 $\mu\text{g/g}$ depending on variety and growth conditions [31, 32], supplies not only β -carotene, a precursor of vitamin A, but also other nutrients such as vitamins, minerals, fibre, and antioxidants [33, 34]. Additional ingredients included soybean (MAKSOY 3 N, *Glycine max*), known to have protein content ranging from 20 to 30% and lipid content from 5 to 22% [35]; and silver fish (*Rastrineobola argentea*), which contains protein in the range of 58–62% [36]. In addition, iron-rich beans (*Phaseolus vulgaris*), with iron content ranging from 80 to 100 mg/kg, was included [37]. Cereals, mainly white maize (*Zea mays*) and red sorghum (*Sorghum bicolor*) of local

Table 1 Socio-demographic characteristics of caregivers who participated in the sensory evaluation of nutrient-dense composite formulae porridges in Northern Uganda (n = 47)

Variable	Response options	Percentage/ mean or median
Sex	Male	2.1
	Female	97.9
Education level	No formal education	1.2
	Primary	74.5
	Post primary	24.3
Occupation	Peasant farmer	97.9
	Business	2.1
Marital status	Married	51.1
	Widowed	29.8
	Others	19.1
Religious affiliation	Catholic	54.4
	Protestant	39.1
	Pentecostal	6.5
Age (mean $\pm$ sd)		47.5 $\pm$ 11.1
Level of income (median: min, max)		40,000: 0, 300,000
Household size (median: min, max)		9: 5, 17
Number of household members with NS (median: min, max)		1: 1, 5

varieties, were included to supply energy, with maize providing 358–406 kcal/100 g and sorghum providing 329–360 kcal/100 g [38–40]. Finally, chia seeds (*Salvia hispanica*) were included as the main source of selenium, as they contain selenium in the range of 8.5–78 µg/100 g [41, 42]. For vulnerable groups, especially those requiring nutritional support for managing undernutrition in NS, these components were specifically chosen to address macronutrient and micronutrient deficiencies. To provide a balanced supply of energy, protein with a variety of amino acids, essential fatty acids, and key micronutrients including iron, selenium, and provitamin A, the ingredients were sourced from both plant and animal origins. As shown in our earlier publication [43], the level of inclusion of the food ingredients resulted in formulations which satisfied the set nutrient conditions, as shown in Table 2.

Processing of the ingredients included in the formulations

A range of food-grade processing methods were used to prepare the composite formulae, based on traditional methods employed by households in the study area. In brief, both sorghum and maize were cleaned by winnowing. Sorghum was then malted for 48 h, sun-dried for 48 h, and oven-roasted [44, 45]. Maize was polished or dehulled once [46]. Legumes and oilseeds, including soybean and chia, were cleaned and oven-roasted [47]. Iron-rich beans were cleaned and stored under dry conditions. OFSP was peeled, washed, grated, and sun-dried for 48 h [48]. Silverfish was cleaned and oven-roasted [49]. After processing, all ingredients were blended in varying proportions and milled to a uniform particle size of 0.25 mm. This particle size ensured smooth texture, consistent gelatinisation, and improved palatability of the porridge, which was critical for caregiver-reported acceptability as a proxy for patient acceptance [50, 51]. A fine particle size ensures better mouthfeel, reduces lump formation during cooking, and allows for consistent blending of nutrient-dense ingredients [52].

Preparation of porridges and sensory evaluation procedure

The composite formulae were used to prepare porridge gruel to the recommended spoonable consistency by mixing the composite flours with water at ratios of 40% and 20% w/v for flours with malted cereals and those without malted cereals, respectively. The mixture was boiled for 15 min at 95 °C, as previously described by Alowo et al. and Nurmomade et al. [53, 54]. This followed the traditional cooking method in the study area. After preparation, porridge from each sample was served in plastic disposable cups. All samples were presented together to each panelist. To minimise order effects, the samples were randomly coded and presented simultaneously. Panelists evaluated all porridge samples in a single session. Each sample was rated once per panelist using a 5-point hedonic scale (1 = dislike very much to 5 = like very much), and there was no replicate evaluation conducted. One bottle of mineral water was provided for rinsing the mouth between tasting the samples [55].

The organoleptic characteristics assessed were appearance, aroma, colour, texture, mouthfeel, aftertaste, and overall acceptability. The 5-point hedonic scale used in sensory evaluation is particularly important when sensory panelists are community members who are untrained and may have difficulty distinguishing differences on higher scales such as the 7-point and 9-point scales [56]. After the sensory evaluation, participants completed a short questionnaire assessing their socio-demographic and household characteristics likely to affect the acceptability of such products.

Statistical analysis

Stata software version 14 was used for data analysis to compute descriptive statistics (mean, frequencies, percentages, median, and standard deviation). Prior to this, data for continuous variables were checked for normality to determine whether to present the mean and standard deviation or the median in cases of non-normality. One-way Analysis of Variance (ANOVA) was used to assess significant differences in sensory scores among

Table 2 Level of inclusion of ingredients in the formulation

Ingredients used	Formulations developed and evaluated							
	Maize-based formulae				Sorghum-based formulae			
	205	715	522	270	200	510	420	277
Maize or sorghum (%)	100	60	65	70	100	60	65	70
Silver fish (%)	0	2	3	2	0	2	3	2
Soybean (%)	0	20	15	15	0	20	15	15
OFSP (%)	0	10	5	5	0	10	5	5
Iron rich beans (%)	0	3	5	3	0	3	5	3
Chia seeds (%)	0	5	7	5	0	5	7	5
Total (%)	100	100	100	100	100	100	100	100

The proportional contribution of each ingredient was expressed as a percentage (%) of the total composite formula by weight.

Table 3 Caregivers' hedonic scores of sensory attributes of maize-based nutrient-dense composite formulae for nodding disease cases in northern Uganda

Sample code	Colour	Taste	After taste	Smell	Thickness	Texture	Overall acceptability
205	4.4 ^c ± 0.9	4.4 ^c ± 0.9	4.1 ^c ± 1.1	4.3 ^c ± 1.0	4.2 ^b ± 0.9	4.4 ^b ± 0.8	4.1 ^b ± 1.3
715	2.8 ^{ab} ± 1.2	2.5 ^a ± 1.3	2.3 ^a ± 1.3	2.1 ^a ± 1.2	2.8 ^a ± 1.2	3.0 ^a ± 1.3	3.2 ^a ± 1.3
522	2.6 ^a ± 0.9	3.1 ^b ± 1.3	2.6 ^{ab} ± 1.2	2.7 ^{ab} ± 1.1	3.0 ^a ± 1.1	3.3 ^a ± 1.1	3.6 ^{ab} ± 1.2
270	3.2 ^b ± 1.0	3.3 ^b ± 1.4	3.1 ^b ± 1.3	3.0 ^b ± 1.3	3.0 ^a ± 1.3	3.3 ^a ± 1.4	3.8 ^b ± 1.2

Values are means ± standard deviation of rating of sensory attributes; different letters in the same column indicate significant differences in rating of the attributes of different formulations ($P \leq 0.05$, Tukey's HSD test)

205:100% Maize; 715: 60:2:20:10:3:5 in the order of maize: silver fish: soybean: OFSP: beans: chia seeds respectively; 522: 65:3:15:5:5:7 in the order of maize: silver fish: soybean: OFSP: beans: chia seeds respectively; 270: 70:2:15:5:3:5 in the order of maize: silver fish: soybean: OFSP: beans: chia seeds respectively

Table 4 Care givers' hedonic rating of sensory attributes of sorghum-based nutrient-dense composite formulae for nodding disease cases in northern Uganda

Sample code	Colour	Taste	After taste	Smell	Thickness	Texture	Overall acceptability
200	3.6 ^b ± 1.1	3.2 ^b ± 1.2	2.6 ^a ± 1.2	3.1 ^b ± 1.5	3.4 ^b ± 1.4	3.2 ^{ab} ± 1.3	3.7 ^{ab} ± 1.2
510	2.7 ^a ± 1.4	2.6 ^a ± 1.3	2.5 ^a ± 1.2	2.5 ^a ± 1.2	2.3 ^a ± 1.3	2.8 ^a ± 1.3	3.4 ^a ± 1.4
420	3.2 ^{ab} ± 1.2	3.7 ^{bc} ± 1.9	3.4 ^b ± 1.2	3.3 ^{bc} ± 1.3	3.5 ^b ± 1.2	3.2 ^{ab} ± 1.3	4.1 ^{bc} ± 0.8
277	3.3 ^b ± 1.2	4.0 ^c ± 1.2	3.4 ^b ± 1.2	3.7 ^c ± 1.2	3.9 ^b ± 1.1	3.4 ^b ± 1.2	4.3 ^c ± 0.9

Values are means ± standard deviation of rating of sensory attributes; different letters indicate significant differences in rating of the attributes of different formulations ($P \leq 0.05$, Tukey's HSD test)

200:100% Sorghum; 510: 60:2:20:10:3:5 in the order of sorghum: silver fish: soybean: OFSP: beans: chia seeds respectively; 420: 65:3:15:5:5:7 in the order of sorghum: silver fish: soybean: OFSP: beans: chia seeds respectively; 277: 70:2:15:5:3:5 in the order of sorghum: silver fish: soybean: OFSP: beans: chia seeds respectively

the different composite formulae evaluated. For multiple comparisons, Tukey's honest significant difference (HSD) post hoc test was performed. Additionally, multiple linear regression was used to explore associations between sensory attributes and other sociodemographic characteristics with overall acceptability of composite formulae 270 and 277. Prior to analysis, key regression assumptions such as normality, multicollinearity, and homoscedasticity were assessed, given a sample size of 47. An independent t-test was used to determine the significant difference in hedonic scores between maize- and sorghum-based formulae, following Levene's test for equality of variance. All tests were conducted at a 5% significance level with a 95% confidence interval.

Ethical consideration

Ethical approval was obtained from the Gulu University Research Ethics Committee (registration number GUREC-2022-258) and the Uganda National Council for Science and Technology (A234ES). During the sensory evaluation, only participants who gave informed consent were included in the study. Local leaders and health officials in the study area were informed that the exercise was not a treatment but an evaluation of a potential intervention for the NS condition.

Results

Overall acceptability scores of composite formulae based on different attributes

Sensory scores of the composite formulae generally increased as the proportion of cereal grains increased,

rising from 3.2 to 3.8 out of five on the hedonic scale in the maize-based formulae, and from 3.4 to 4.3 out of five in the sorghum-based formulae. Across the different formulae, there were significant differences in some pairwise comparisons ($p < 0.05$), while some combinations did not show any significant difference ($p > 0.05$).

For maize-based formulae (Table 3), the control sample 205 (100% maize) had a significantly higher ranking for colour, taste, aftertaste, thickness, and texture compared to all other composite formulae ($p < 0.05$). However, the overall acceptability of the control, composite formula 522 (65% maize), and composite formula 270 (70% maize) were not significantly different ($p > 0.05$). Furthermore, the overall acceptability of composite formula 715 (60% maize) was significantly lower than both the control and composite formula 270 ($p < 0.05$). Comparison between the formulations revealed that composite formula 270 had a significantly better rating for taste, smell, and aftertaste compared to composite formula 715 ($p < 0.05$). In contrast, texture and thickness were not significantly different among the three maize-based formulae ($p > 0.05$). With the exception of colour, there was no significant difference between composite formulae 522 and 270 for any other attribute, including overall acceptability ($p > 0.05$).

There were significant differences ($p < 0.05$) among the formulae regarding the attributes of sorghum-based formulae (Table 4). Unlike the maize-based formulae, composite formula 200 generally scored lower than composite formulae for most attributes except colour. This formula did not show any significant difference compared with 420 (65% sorghum) and 277 (70% sorghum) for the

colour attribute ($p > 0.05$). Furthermore, composite formulae 200 (100% sorghum) and 510 (60% sorghum) were not significantly different in many organoleptic characteristics, like aftertaste, texture, and overall acceptability ($p > 0.05$). In addition, composite formulae 420 and 277 showed no significant differences across all organoleptic characteristics ($p > 0.05$). Based on these acceptability scores, both 277 and 420 appear promising for scaling up, using the caregivers' rating as a proxy for overall acceptability by NS patients.

Table 5 Comparison of care givers' ratings for sensory attributes between maize-based and sorghum-based nutrient-dense composite formulae for NS cases in northern Uganda

Formulations	Organo- leptic property	t (p-value)	Mean scores and mean difference (MD)		
			Maize	Sorghum	MD
Control (100%) maize/sorghum	Colour	3.2 (0.002)	4.3*±1.2	3.5±1.2	0.8
	Taste	4.2 (<0.001)	4.3*±1.2	3.2±1.3	1.1
	After taste	5.3 (<0.001)	4.0*±1.3	2.6±1.3	1.5
	Smell	3.9 (<0.001)	4.2*±1.2	3.0±1.6	1.2
	Thickness	2.8 (0.006)	4.1*±1.1	3.3±1.4	0.8
	Texture	4.2 (<0.001)	4.3*±1.1	3.1±1.4	1.1
	Overall acceptability	1.4 (0.178)	4.0±1.5	3.6±1.3	0.4
60% maize/sorghum	Colour	0.2 (0.848)	2.7±1.2	2.7±1.4	0.1
	Taste	-0.4 (0.712)	2.5±1.3	2.6±1.3	-0.1
	After taste	-0.8 (0.440)	2.3±1.3	2.5±1.2	-0.2
	Smell	-1.4 (0.155)	2.1±1.2	2.5±1.3	-0.4
	Thickness	1.6 (0.128)	2.7±1.2	2.3±1.3	0.4
	Texture	0.5 (0.633)	2.9±1.3	2.8±1.3	0.1
	Overall acceptability	-0.6 (0.539)	3.1±1.4	3.3±1.4	-0.2
65% maize/sorghum	Colour	-2.4 (0.018)	2.6*±1.1	3.2±1.3	-0.2
	Taste	-1.9 (0.056)	3.1±1.3	3.6±1.3	-0.6
	After taste	-0.6 (0.005)	2.5*±1.3	2.8±1.0	-0.3
	Smell	-2.9 (0.020)	2.5*±1.3	3.3±1.3	-0.8
	Thickness	-2.4 (0.049)	2.6*±1.2	3.3±1.4	-0.7
	Texture	-0.1 (0.893)	3.2±1.2	3.2±1.3	-0.0
	Overall acceptability	-1.6 (0.122)	3.6±1.3	4.0±1.0	-0.4
70% maize/sorghum	Colour	-0.2 (0.835)	3.2±1.1	3.2±1.3	-0.1
	Taste	-2.0 (0.047)	3.2*±1.5	3.8±1.3	-0.6
	After taste	-1.2 (0.253)	3.0±1.4	3.4±1.3	-0.3
	Smell	-2.3 (0.025)	2.9*±1.4	3.6±1.3	-0.7
	Thickness	-2.9 (0.005)	3.0*±1.4	3.8±1.3	-0.8
	Texture	-0.5 (0.638)	3.2±1.5	3.3±1.3	-0.1
	Overall acceptability	-1.7 (0.102)	3.7±1.4	4.2±1.1	-0.5

* Indicates significant difference at $p < 0.05$

Comparison of organoleptic characteristics of maize and sorghum composite formulae

Significant differences ($p < 0.05$) were observed in all attributes of the two product lines (taste, smell, colour, aftertaste, texture, and thickness) except for overall acceptability ($p > 0.05$) (Table 5). At the 60% ratio, no significant difference was found between the maize- and sorghum-based formulae. However, at 65% and 70% cereal content in the composite formulae, the sorghum-based formulae generally scored higher than the maize-based formula for colour, texture, taste, smell, aftertaste, thickness, and overall acceptability. When the 65% composite formulae were compared, significant differences were found for colour, aftertaste, smell, and thickness ($p < 0.05$). For the 70% formula, significant differences were observed for taste, smell, and thickness ($p < 0.05$).

Determinants of overall acceptability for the most liked composite formula for the nutrient-dense composite formulae

The determinants, as shown in Table 6, were analysed for two composite formulae (270 and 277) because these were the most preferred by the caregivers, who were used as a proxy for the acceptability by NS. Both formulae, 270 and 277, contained 70% maize and sorghum, respectively. The overall acceptability of composite formula 270 increased with higher taste ratings ($\beta = 0.608$, $p = 0.017$). However, for this formula, texture showed a negative relationship, where an increase in the texture score decreased overall acceptability ($\beta = -0.584$, $p = 0.015$). Furthermore, for this formula, overall acceptability also increased with higher ratings of thickness ($\beta = 0.510$, $p = 0.025$). Regarding sociodemographic characteristics, the overall acceptability of formula 270 increased for caregivers who had attained primary education ($\beta = 0.945$, $p = 0.046$), while age showed a negative relationship ($\beta = -0.066$, $p = 0.005$). Finally, for this composite formula, the number of children under two years in the caregiver's household showed a negative relationship with overall acceptability ($\beta = -0.902$, $p = 0.003$). For composite formula 277, overall acceptability was positively influenced by higher taste ratings ($\beta = 0.621$, $p < 0.001$), higher texture ratings ($\beta = 0.192$, $p = 0.043$), and increasing age of the caregivers ($\beta = 0.020$, $p = 0.011$).

Discussion

This study evaluated the organoleptic properties influencing the acceptability of nutritional formulae from local ingredients for nutritional intervention in NS in northern Uganda. The study found that formulations from local foods have good levels of acceptability compared to the control based on common staple cereals. Although the control received significantly better ratings in some sensory attributes, the non-significant difference

Table 6 Factors influencing overall acceptability of most liked nutrient-dense composite formulae porridge by caregivers of nodding syndrome cases in northern Uganda

Composite formula 270				Composite formula 277		
Attribute/variable	Coefficient	t	P>t	Coefficient	t	P>t
Colour	-0.329	-1.47	0.160	-	-	-
Taste	0.608*	2.62	0.017	0.621*	5.66	<0.001
Thickness	0.51*	2.44	0.025	-	-	-
Texture	-0.584*	-2.68	0.015	0.192*	2.11	0.043
Age	-0.066*	-3.18	0.005	0.02*	2.73	0.011
Education						
Primary	0.945*	2.14	0.046	-	-	-
Religion						
Protestant	-0.693	-1.79	0.090	-0.38	-1.88	0.07
Pentecostal	-1.202	-1.79	0.090	-0.78	-1.6	0.121
Number of children < 2	-0.902*	-3.44	0.003	-	-	-
Marital status						
Widowed	0.816	1.65	0.116	-	-	-
Divorced	-0.781	-1.41	0.176	-	-	-
Household size						
6 to 10	-	-	-	-0.823	-1.99	0.056
Above 10	-	-	-	-0.978	-1.88	0.07
Constant	8.591*	4.88	<0.001	1.121*	2.58	0.015

* Indicates significance at $p < 0.05$, composite formula 270 = maize-based formulation, composite formula 277 = sorghum-based formulation; dashes indicate variables dropped due to estimability. overall acceptability of composite formula 270 (with 70% maize; 15% soybean, 5% OFSP, 5% chia seeds, 3% iron rich beans and 2% silver fish) and composite formula 277 (with 70% sorghum, 15% soybean, 5% OFSP, 5% chia seeds, 3% iron rich beans and 2% silver fish); * = significant at 5%; dashes for composite formulae 270 and 277 mean those variables were dropped because of estimability

in overall acceptability indicates the promising role these composite formulae can play in addressing under-nutrition among individuals affected by NS. Previously, food composite formulae have been rated lower in preference scores than the unimproved versions for cassava-chia composite formulae porridge in Tanzania [57]. This may be due to familiarity with unimproved, commonly consumed foods.

Acceptability scores of composite formulae based on different attributes

The proportion of individual ingredients can influence the organoleptic properties of food composite formulae in various ways [58, 59]. In this study, the composite formula containing 60% maize (715) scored lower in all attributes compared to the composite formula with 65% (522) or 70% maize (270). Consequently, the overall acceptability of 522 and 270 is higher than that of 715. Specifically, sensory attribute such as texture have previously been found to be influenced by the proportion of staples such as maize [59]. Due to the inclusion of other ingredients, attributes such as taste, colour, texture, and smell are also affected. In typical NS-affected households in northern Uganda, maize is consumed either as porridge or as a bread meal. The absence of a significant difference in overall acceptability between the control meal composite formulae made of 100% maize and those with 65% and 70% maize implies that the improved composite formulae

are equally acceptable relative to the control. Therefore, they can be used as alternatives, providing additional nutritional benefits using locally available foods.

For sorghum-based formulae, observation shows no significant difference in colour between the control (200) and formulations containing 65% (420) and 70% (277) sorghum. This may be due to the similar proportions of sorghum in the composite formulae compared with the control, resulting in a colour close to that of the control. The stability of the colour rating with increased sorghum content suggests that, visually, the product is acceptable to caregivers and therefore to the target users. This is important because individuals with NS often experience feeding difficulties, reduced appetite, and sensitivity to sensory changes [60]. This result is consistent with findings from Nigeria [61] and Kenya [56], where the control for sorghum composite formulae were comparable with the improved product lines in terms of colour. Furthermore, the lack of significant difference when the control was compared with the composite formula containing 60% sorghum could be due to the high proportion of orange-fleshed sweet potatoes (OFSP) in the composite formula containing 60% sorghum. OFSP is known to strongly influence most organoleptic characteristics, especially colour, flavour, and appearance [62]. In addition, the control formula lacked other ingredients such as soybean and chia, which are known to improve the organoleptic quality of composite formulae, including

appearance, texture, flavour, smell, and overall acceptability [63–65]. Another observation, where composite formulae with 65% and 70% sorghum showed no significant difference in all attributes, could be due to equal proportions of soybean and OFSP in both formulation, that are known to influence many organoleptic appeal including colour [66]. Scoring highly with no significant difference means any of these two composite formulae (420 and 277) can be scaled up for intervention. This concurs with a study by Adejumo et al. [61], which affirms the favorable overall acceptability of improved sorghum composite formulae.

The results suggest that caregivers of NS found the composite formulae porridge acceptable, with statistically significant differences across formulations. However, differences of less than one point (e.g., 0.3 to 0.5 points) on a 5-point hedonic scale may not translate into meaningful changes in adoption. While statistically significant, such small changes should be interpreted cautiously when considering programmatic relevance. Finally, these findings should be viewed as indicative rather than definitive.

Comparison of organoleptic characteristics of maize and sorghum composite formulae

The observation that overall acceptability increased with an increase in the proportion of cereals (sorghum and maize) in the formulation implies that uptake by caregivers and NS persons, as well as adherence, will be higher when the proportion of cereal is maintained at higher levels, provided the nutrient density, safety, and functional properties of the composite formulae are preserved. This is likely because the formulations resembled the familiar cereals that caregivers were accustomed to. This finding is comparable to a study by Sanya et al. [67], where consumer acceptability of extruded maize-sorghum composite formulae fortified with grain amaranth, baobab, and orange-fleshed sweet potatoes in the ratio of 20:45:5:15:15 for maize: sorghum: amaranth: OFSP: baobab, respectively, increased with a higher proportion of cereal grains. The observation that sorghum-based formulae scored higher than maize-based formulae for composite formulae with 65% and 70% cereals could be attributed to the roasting process of malted sorghum, which may have enhanced its organoleptic characteristics such as colour, taste, and aroma through the Maillard reaction, thereby altering these properties to better suit consumer preferences. This is supported by previous studies in India by Ranganathan et al. [68], and in Nigeria by Msheliza et al. [69], where composite formulae from roasted sorghum scored higher than their non-roasted counterparts.

Factors that affected overall acceptability of composite formulae

The overall acceptability of the composite formulae developed was influenced by specific organoleptic and socio-demographic characteristics, depending on the main ingredients used (Table 6). For maize-based formula 270, the positive association between taste and overall acceptability may be because positive taste experiences trigger reward pathways in the brain, reinforcing consumption behaviour in favour of overall acceptability [70]. This suggests that uptake by caregivers and continued adherence by NS cases will depend on optimising taste within a familiar range. In practice, as this product targets NS cases, taste should be considered a constraint in decision-making, and the sensory attribute of maize should be preserved. This should be achieved while considering nutrient-dense aspects and processing techniques that improve acceptability without masking the product's taste. These results also confirm the postulation that food taste is an inherent quality attribute and can significantly influence food acceptability, selection, and consumption [71]. This finding is comparable with findings by Kikafunda et al. [72], on maize-beans composite formula as well as by Tortoe et al. [73], on yam-cowpea-soybean porridge. Conversely, the negative relationship between texture and overall acceptability could be due to the high proportion of maize in the formulation, where some coarse and irregular particles may have escaped the sieve. This finding has implications for both product formulation and scaling up. It underscores the need to optimise texture as a critical determinant of adherence, even when nutrient density and taste have been prioritised. Additionally, soybean and iron-rich bean flours are known to have coarse textures [74], which could further contribute to the undesirable texture of the composite formulae. In a similar study by Kikafunda et al. [72], the texture of a maize-bean porridge blend was found to be the least liked organoleptic attribute, while Gitau et al. [75], also noted that texture was the least liked attribute of porridge blends made from cereals, pseudocereals, tubers, and roots. This implies that nutritional improvement alone may not be sufficient if textural quality is neglected. Therefore, addressing challenges with texture is essential not only for consumer acceptance but also for ensuring sustained use of nutrient-enriched composite formulae in vulnerable populations, such as NS cases in northern Uganda.

Overall acceptability increased with higher ratings of porridge thickness. Thickness of porridge can be influenced by several factors such as flour-to-water ratio, where higher flour content per batch yields greater viscosity hence thickness [76], and it was the same situation in this study. This suggests that optimising viscosity or thickness is a crucial parameter which should always

be considered when formulating maize-based porridge, especially for children with NS in northern Uganda. During preparation, caregivers should aim for thicker consistencies, as this positively influences sensory appeal and thus compliance. Although thinner porridges are easier to prepare, such consistencies risk rejection and/or reduced intake. Before scaling up, caregivers and health workers should be trained to consistently achieve the preferred thickness, ensuring uniformity in acceptability and, consequently, success. The high proportion of unmalted maize in the formulation can contribute to a high starch content in the porridge. Starch content affects the extent of retrogradation, which influences thickness as the porridge cools [77]. This is consistent with a previous study in Kenya on consumer preference for porridge blends from cereals, pseudocereals, tubers, and roots [75], where porridge thickness positively influenced overall acceptability. Considering demographic factors, the level of acceptability of this formula was higher among caregivers who had attained primary education compared to those without formal education, possibly because educated individuals are more likely to understand the health benefits of composite formula [78]. In addition, a higher level of education correlates with openness to novel foods, such as blended or fortified porridges [79]. This observation highlights the critical role of caregivers' basic education level in the uptake of nutrition interventions. Therefore, implementers of the intervention should design simplified, pictorial, and easy-to-use training materials to bridge this comprehension gap for caregivers without formal education. Furthermore, community awareness campaigns should make use of oral communication, role plays, and peer-led demonstrations so that caregivers with lower education levels can still prepare and appreciate the porridge formula. This is consistent with a previous study by Aboje et al. [80], which found that the overall acceptability of porridge made from maize, wheat, and soybean increased with higher levels of education. The education level of a caregiver has a significant impact on the nutrition of the child [81], as it determines the caregiver's ability to select and provide foods which are safe and nutritious, leading to better health outcomes. The negative influence of caregivers' age on the overall acceptability of formulations could be attributed to health conditions and changing sensory preferences associated with ageing. For instance, older married women who are caregivers are more likely to be attentive to dietary choices that do not affect their own health or that of their family [80]. This highlights the age-related aspect of intervention uptake in NS, particularly from a nutritional perspective. Therefore, nutrition education should be age-sensitive, using culturally resonant messages and demonstrations that address skepticism among older caregivers. Food-based

interventions in NS must incorporate inclusive, participatory approaches such as community taste panels, where older caregivers are actively involved, even in formulation trials. This will foster ownership, which reduces resistance. Finally, the decrease in overall acceptability of formula 270 with an increase in the number of children under two years in households could be attributed to fatigue from caring for NS cases, making households hesitant to welcome more children due to fear of future affliction by nodding syndrome. In addition, where porridge preparation is perceived as labour-intensive, caregivers with many children under two years are less likely to adopt or accept the formula. Therefore, simplifying the preparation steps and reducing cooking time could mitigate this concern among caregivers.

For the sorghum-based composite formula 277, the positive association between taste and overall acceptability may be due to processing techniques such as roasting, which results in the Maillard reaction, and malting, which leads to starch conversion to sugar; both processes contribute to improved product quality [82, 83]. This finding suggests that taste preferences are culturally embedded, and aligning porridge flavour profiles with local tastes in northern Uganda will strengthen community ownership and minimise resistance to intervention foods. Nutrition guidelines should clearly recognise taste optimisation as a measurable quality standard in food development, as in the NS context. In a similar study, Agbor et al. [84] showed that malted sorghum-soy composite formula significantly improved the products' taste rating. Additionally, the texture of the formula positively influenced its overall acceptability. This may be due to improved smoothness and reduced lumpiness resulting from the enzymatic breakdown of starch during malting [85]. Therefore, intervention food composite formulae should deliberately standardise porridge texture, considering smoothness, viscosity, and graininess in alignment with local preferences. For NS cases, who may have difficulties chewing and swallowing, acceptable food textures can facilitate consumption and reduce feeding resistance. Previous studies on food texture, such as Gitau et al. [75] and Kikafunda et al. [72], also found a positive influence on the overall acceptability of food composite formulae in Kenya and Uganda respectively. The overall acceptability of the composite formula increased with the age of the caregivers. One possible reason is cultural familiarity with sorghum meals, as opposed to maize meals, in the study area. Additionally, older caregivers may be less sensitive to minor sensory imperfections compared to children or adolescents. This agrees with Haile and Shufa [86], who found that porridges with chickpea-kocho blends were more acceptable to older panelists. However, this finding contrasts with previous results from Kenya and South Africa, where age negatively influenced

sensory scores [75, 87]. The different contexts in which these studies were conducted, as well as socio-demographic differences among the panelists could explain these contrasting findings.

Strengths and limitations of the study

A key strength of this study is its ability to address the paucity of literature, particularly regarding the assessment of organoleptic drivers of caregiver-reported acceptability of nutrient-dense composite formulae made from local materials, specifically targeting medically managed NS cases. It is therefore one of the few studies examining NS management using a food-based approach with formulae developed from local materials. One limitation is the use of caretakers' preference scores as a proxy for the organoleptic acceptability by NS cases. In addition, the study used purposive sampling to select participants, a method prone to selection bias. This study employed only a quantitative approach to data collection, whereas qualitative methods such as focus group discussions could have provided additional information. Furthermore, evaluating all samples in a single session could have led to fatigue, while simultaneous presentation may have encouraged direct comparison rather than independent assessment. Each sample was rated only once per panelist, without replication, which may limit reliability. While this study offers valuable insights into the organoleptic characteristics influencing the acceptability of the developed formulae, future research should consider qualitative approaches such as focus group discussions and increase the sample size to validate the sensory scores, better understand the contextual determinants of these scores, and address bias. Furthermore, future research on this type of population group should consider incorporating patient-centered sensory evaluations, where ethically and practically feasible, to strengthen the validity of acceptability findings.

Conclusion

This study highlights the potential of nutritionally enhanced cereal-based food products to be accepted by NS patients, having used their caregivers' acceptability rating as a proxy of their own acceptability of the composite formulae. The composite formulae made from both maize- and sorghum-based formulae was well accepted by the population, especially the caregivers of NS patients. Organoleptic factors such as taste, texture, smell, and thickness of these products vary and significantly affect overall acceptability. Therefore, formulating nutrient-enhanced products should consider not only nutritional value but also sensory properties to improve acceptability. Sociodemographic factors such as education level, age, and number of children also influenced acceptability, from the perspective of the caregivers who

were used as proxies for NS patients. The study concludes that composite formulae made from locally available nutrient-rich foods, with 70% sorghum or maize, are highly acceptable by caregivers of NS whose preference scores were used as a proxy for the organoleptic acceptability by NS cases. Therefore, the above formulae could undergo further analysis to inform their use among people with NS, while taking into account sociodemographic factors. The study provides recommendations for promoting the nutrient-dense composite formulae in this context on the basis of acceptability of caregivers of NS.

Abbreviations

ANOVA	Analysis of variance
GUREC	Gulu University research ethics committee
HSD	Honest significant difference
LRA	Lord's Resistance Army
MT	Metric tonnes
NS	Nodding syndrome
OFSP	Orange fleshed sweetpotato
UBOS	Uganda bureau of statistics
UNCST	Uganda national council for science and technology

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Authors' contributions

BA, DO, FOA, BO, and SO conceptualised the study as well as its overall implementation. BA, SO and DO drafted the manuscript. BA analysed the data. BA, DO, FOA, BO, and SO revised the manuscript critically especially for intellectual content. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. It was approved by the Gulu University Research Ethics Committee (registration number GUREC-2022-258) and received clearance from the Uganda National Council for Science and Technology (A234ES). Respondents provided informed consent before the survey began. Anonymity and confidentiality were ensured throughout the study period.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Department of Food Science and Postharvest Technology, Faculty of Agriculture and Environment, Gulu University, Gulu City, Uganda

²Department of Science and Vocational Education, Faculty of Education, Lira University, Lira City, Uganda

³Department of Nutrition and Dietetics, Faculty of Public Health, Lira University, Lira City, Uganda

⁴Department of Internal Medicine, Faculty of Medicine, Lira University, Lira City, Uganda

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