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Determinants of Adoption and Sustainability of Underutilized Species-Based Nutrition Interventions among Rural Households in Northern Sierra Leone

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Abstract

Food-based strategies built on locally available underutilized species are widely promoted as sustainable responses to micronutrient deficiency, yet many such interventions fail not because the foods lack nutritional value but because households do not take them up and keep using them. This study examined the socio-economic, cultural, and institutional factors that shape adoption and sustained use of processed products derived from three underutilized species: mango (*Mangifera indica*), orange-fleshed sweet potato (OFSP; *Ipomoea batatas*), and pumpkin (*Cucurbita* spp.) in Bombali and Tonkolili Districts, Northern Sierra Leone. A cross-sectional mixed-methods design was used, combining a structured survey of 400 rural households with focus group discussions and key-informant interviews. Adoption of processed underutilized products was modelled using multivariable logistic regression adjusted for socio-demographic, economic, and institutional covariates, and qualitative data were analysed thematically. Despite high reported availability (mango 86.5%, pumpkin 75.5%, OFSP 60.0%), underutilization indices exceeded 30% for all three species, confirming a substantial gap between what households can obtain and what they routinely eat. Six factors were independently associated with adoption: exposure to nutrition education (AOR = 1.74; 95% CI: 1.28–2.36; $p < 0.001$), sensory acceptability (AOR = 1.68; 1.34–2.11; $p < 0.001$), cultural food preference (AOR = 1.53; 1.19–1.96; $p = 0.001$), perceived shelf-life benefit (AOR = 1.42; 1.11–1.82; $p = 0.005$), female household headship (AOR = 1.36; 1.01–1.83; $p = 0.043$), and household income level (AOR = 1.29; 1.03–1.62; $p = 0.027$). District of residence showed no independent effect (AOR = 1.12; 0.84–1.50; $p = 0.441$). Qualitative accounts converged on the same picture: households described the staple-centred structure of meals, a narrow repertoire of preparation methods, unreliable off-season supply, women's time burden, and the absence of processing equipment and training as the practical limits on regular use, while familiarity, visible benefit for children, and peer demonstration encouraged uptake. Adoption in this setting is therefore driven by knowledge and experience rather than by geography or supply alone, and sustainability depends on whether interventions reduce, rather than add to, the everyday effort of preparing food. Programmes that pair practical processing training with sensory-led product design, reliable year-round supply, and support for women's workload are the most likely to endure.

Keywords: Adoption; Nutrition Education; Sensory Acceptability; Sierra Leone Underutilized Species.

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INTRODUCTION

Micronutrient deficiency remains one of the most persistent public health problems in low-income rural settings, and vitamin A deficiency continues to affect large numbers of preschool children and women of reproductive age across sub-Saharan Africa (UNICEF, 2023; WHO, 2022; FAO et al., 2023). Over the past decade, policy attention has shifted from supplementation alone towards food-based, nutrition-sensitive strategies that draw on locally available agricultural biodiversity, on the argument that such approaches are more sustainable, more culturally acceptable, and less dependent on external inputs (Burlingame & Dernini, 2018; Fanzo et al., 2021). Underutilized and neglected species occupy a central place in this agenda: they are frequently more micronutrient-dense than dominant staples, are adapted to marginal environments, and are already present in the food environments of the households that need them most (Padulosi et al., 2016; Hunter et al., 2019; Mabhaudhi et al., 2019).

Presence, however, is not the same as consumption. In Bombali and Tonkolili Districts of Northern Sierra Leone, mango, orange-fleshed sweet potato (OFSP), and pumpkin are widely available, yet none of them contributes to household diets at a frequency commensurate with that availability. This availability, utilization gap has been documented repeatedly across the region and is generally attributed to perishability, seasonality, narrow preparation repertoires, weak markets, and the low social status attached to indigenous foods (Padulosi et al., 2016; HLPE, 2020; Turner et al., 2020). Small-scale processing is the intervention most often proposed to close it, because it addresses perishability and seasonality directly while improving convenience and palatability (Grace et al., 2018; FAO, 2018).

A companion analysis of the same study established that this technical premise holds in the study setting. Simple, community-level processing of the three species extended mean shelf life from 6.1 to 66.4 days at an estimated cost of roughly 12% of vitamin A content, and significantly improved sensory acceptability for every product category tested; Mango juice recorded a mean overall acceptability score of 8.2 ± 0.6, while pumpkin–mango purée achieved 7.4 ± 0.8 on a 9-point hedonic scale. That analysis, however, answered a technical question rather than a behavioural one. Demonstrating that a product can be made, kept, and liked under study conditions says little about whether households will incorporate it into ordinary meals, and less about whether they will still be doing so once the study team has left. The history of food-based nutrition programming in the region is full of technically sound interventions that were adopted briefly and then abandoned (Ruel et al., 2018; Olney et al., 2021).

The determinants of that second step remain thinly evidenced for underutilized species specifically. Much of the existing literature examines either agronomic potential or laboratory nutrient composition, and where social factors are considered, they are usually treated in isolation gender in one study, market access in another, knowledge in a third, rather than as competing influences estimated within a single model (Hunter et al., 2019; Njuki et al., 2016; Malapit et al., 2019). For Sierra Leone the evidence base is thinner still. This matters in practice because programme designers must choose where to allocate limited resources: in extension and training, in product formulation, in supply reliability, or in market development. Without an estimate of the relative weight of these factors, that choice is made on assumption.

This study addresses that gap. It draws on Food Systems Theory, which situates utilization as a distinct node in the pathway from production to nutrition outcome (HLPE, 2017; Fanzo et al., 2021), and on the Sustainable Livelihoods Framework, which explains household decisions in terms of the human, physical, financial, natural, and social assets available to them under conditions of vulnerability (Scoones, 2015; Ruel et al., 2018). Together these frameworks

predict that adoption will depend less on the objective nutritional merit of a food than on the knowledge, time, equipment, and social endorsement required to use it. The specific objective was to identify the socio-economic, cultural, and institutional factors influencing adoption and sustained use of underutilized species-based products among vulnerable households in Bombali and Tonkolili Districts. Six hypotheses were tested: that adoption would be positively associated with (i) sensory acceptability of the processed product, (ii) perceived shelf-life benefit, (iii) exposure to nutrition education, (iv) alignment with cultural food preference, (v) household income level, and (vi) female household headship; and that (vii) district of residence would show no independent association once these factors were controlled.

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional mixed-methods design was used, integrating a structured household survey with focus group discussions (FGDs) and key-informant interviews (KIIs). Mixed-methods designs are well suited to nutrition research in which measurable behaviours and socially embedded practices must be assessed together (Creswell & Plano Clark, 2018; Turner et al., 2020). The study was conducted in Bombali and Tonkolili Districts, Northern Sierra Leone. Both districts are predominantly rural, with livelihoods based on smallholder farming, seasonal labour, and informal trade, and both experience experiences pronounced lean seasons during which dietary diversity declines sharply (World Bank, 2020; WFP, 2021). They were purposively selected for the combination of high malnutrition prevalence and substantial agro-biodiversity, which is precisely the configuration in which an availability–utilization gap can arise.

Population, Sampling, and Sample Size

The study population comprised rural households in selected chiefdoms of the two districts. The primary survey respondent in each household was a woman of reproductive age (15–49 years). Eligible women who; did not give consent, sick, and non-residents were excluded. Households without eligible women and those absent for three consecutive visits throughout the data collection period were excluded and those with multiple eligible participants, one was randomly selected using an electronic random sampling spin on a mobile device, where all women had equal chances to selected, reflecting the central role of women in food preparation, processing, and child feeding, and their heightened vulnerability to micronutrient deficiency (Ruel et al., 2018; UNICEF, 2020). Multi-stage sampling was applied: chiefdoms were purposively selected on the basis of rurality, agricultural activity, and evidence of food insecurity, and villages were then randomly selected within each chiefdom.

Sample size was calculated using Cochran's formula for a single population proportion, assuming a 95% confidence level, a 5% margin of error, and a conservative proportion of 50% to maximise variability.

$$n = \frac{Z^2 p(1-p)}{d^2}$$

Where:

n = required sample size

Z = standard normal deviate at 95% confidence level = 1.96

p = estimated proportion = 0.50

d = margin of error = 0.05

Substituting:

$$n = \frac{(1.96)^2 \times 0.50(1 - 0.50)}{(0.05)^2}$$

$$n = \frac{3.8416 \times 0.25}{0.0025}$$

$$n = \frac{0.9604}{0.0025} = 384.16$$

This was adjusted upward and rounded to 400 to allow for non-response, incomplete questionnaires, and field recording errors. For the qualitative component, participants women involved in food processing, male household heads, community leaders, agricultural extension workers, and local health authorities were purposively sampled, and data collection continued until thematic saturation was reached (Guest, Namey & Mitchell, 2017).

Data Collection

Quantitative data were collected using a structured household questionnaire covering socio-demographic characteristics, availability and sourcing of the three species, consumption frequency and food form, seasonality and post-harvest loss, nutrition knowledge and education exposure, processing practices and access to processing tools, product acceptability, shelf-life perception, adoption and willingness, and gender and decision-making. Dietary diversity was assessed by 24-hour recall using the Household Dietary Diversity Score and the Women's Dietary Diversity Score (FAO & FHI 360, 2016). FGDs explored community perceptions of the three species, cultural norms, gender roles, and processing practices; KIIs addressed institutional support, extension provision, and market dynamics. All interviews were conducted in local languages, then transcribed and translated into English.

Variables and Measurement

Outcome: The dependent variable was adoption of processed underutilized products, recorded as a binary indicator of whether the household had taken up and was using processed forms of mango, OFSP, or pumpkin. A secondary indicator distinguished regular from occasional use. Willingness to consume the two final study products on a regular basis was recorded separately for the sensory panel.

Predictors: Sensory acceptability was the overall acceptability rating for the processed product on a hedonic scale. Shelf-life perception was an ordinal measure of the respondent's assessment of the storage advantage conferred by processing, from none to very high. Nutrition education exposure was a binary indicator of whether the respondent had received formal or informal nutrition education. Cultural food preference was an ordinal measure of how well the product aligned with the household's existing food culture. Household income level was recorded in three categories (low, medium, high), and female household headship as a binary indicator. District of residence was included to test for residual geographic variation.

Contextual Measures: An Underutilization Index (UI) was computed for each species as the percentage of respondents reporting availability minus the percentage reporting weekly or daily consumption, giving a simple, interpretable measure of the availability–utilization gap.

Acceptability of raw versus processed forms was compared for each species to quantify the change that processing produced.

Statistical and Qualitative Analysis

Descriptive statistics (means, standard deviations, frequencies, percentages) summarised household characteristics, availability, consumption frequency, and processing practices. Paired-sample t-tests compared acceptability of raw and processed forms, with effect sizes reported as Cohen's d. A multivariable logistic regression model was fitted to identify independent predictors of adoption, adjusting simultaneously for socio-demographic, economic, and institutional covariates so that each factor is reported net of the others (Kirkwood & Sterne, 2019). Results are presented as adjusted odds ratios (AOR) with 95% confidence intervals; statistical significance was set at $p < 0.05$, and a confidence interval excluding 1.0 was treated as evidence of an independent association. Qualitative data were analysed thematically using deductive codes derived from the theoretical framework and inductive codes emerging from participant narratives (Braun & Clarke, 2021). Quantitative and qualitative findings were integrated at the interpretation stage to enable triangulation.

Ethical Considerations

Ethical approval was obtained from the Njala University ethics review board. Permission was sought from district authorities and community leaders, and written or thumb-printed informed consent was obtained from every participant prior to data collection, written parental consent forms were thumb-printed or signed on behalf of study participants who were below the age of 18 (15 – 17) while they gave oral consent to participate. Confidentiality and anonymity were maintained through the use of respondent codes, participation was voluntary, and participants were free to withdraw at any stage without consequences.

RESULTS

Household Characteristics

The 400 surveyed households were drawn from Bombali (55.0%) and Tonkolili (45.0%). Half (50.0%) fell in the low-income category, 33.8% in the medium category, and 16.2% in the high category. Just over a third (36.0%) were female-headed, and 71.0% were farming households. Mean household size was 7.02 ± 2.54 persons. Farming was the predominant occupation among respondents (45.2%), followed by civil service (22.6%), with traders and unemployed respondents each accounting for 16.1%. The sample is therefore characteristic of the rural, agrarian, and largely low-income population for which food-based nutrition strategies are intended (Table 1).

Table 1: Socio-demographic characteristics of surveyed households (n = 400).

Variable	Category	Frequency (n)	Percentage (%)
District	Bombali	220	55.0
	Tonkolili	180	45.0
Income level	Low	200	50.0
	Medium	135	33.8
	High	65	16.2

Variable	Category	Frequency (n)	Percentage (%)
Female-headed household	Yes	144	36.0
	No	256	64.0
Farming household	Yes	284	71.0
	No	116	29.0
Household size	Mean ± SD	7.02 ± 2.54	—

Percentages are column percentages within each variable. Household size is reported as a mean with standard deviation.

The Adoption Context: Availability Without Utilization

All three species were widely present in the study communities. Mango was reported as available by 86.5% of respondents, pumpkin by 75.5%, and OFSP by 60.0%. Consumption, however, did not track availability. Weekly or daily consumption was reported by 50.0% of respondents for mango, 40.0% for pumpkin, and 30.0% for OFSP, producing underutilization indices of 36.5%, 35.5%, and 30.0% respectively (Table 2). The ranking is instructive: mango, the most available species, showed the largest gap, while OFSP — by a wide margin the most nutrient-dense of the three — was both the least available and the least consumed. Availability, in this setting, is a poor predictor of dietary contribution.

Table 2: Availability, high-frequency consumption, and underutilization index by species (n = 400).

Species	Availability (%)	Weekly/daily consumption (%)	Underutilization index (%)
Mango	86.5	50.0	36.5
Pumpkin	75.5	40.0	35.5
OFSP	60.0	30.0	30.0

The underutilization index is calculated as reported availability minus the proportion of respondents consuming the species weekly or daily. Higher values indicate a larger gap between what households can obtain and what they routinely eat.

Stated demand for processed forms was nonetheless substantial. Among sensory panellists, 78% indicated willingness to consume the mango juice regularly, and 64% said the same of the pumpkin–mango purée. The gap between this level of stated willingness and actual reported adoption is the phenomenon the regression model was built to explain.

Processing and Sensory Acceptability

Acceptability rose significantly after processing for all three product categories (Table 3). Mean scores increased from 2.81 ± 0.74 to 3.64 ± 0.68 for the pumpkin-based product, from 2.93 ± 0.71 to 3.71 ± 0.65 for the OFSP-based product, and from 3.02 ± 0.69 to 3.85 ± 0.62 for the mango-based product. All differences were significant at $p < 0.001$, with effect sizes of 0.32–0.37. These results are reported here because acceptability was subsequently entered as a predictor in the adoption model; the full processing analysis, including shelf life and vitamin A retention, is reported in the companion paper.

Table 3: Effect of small-scale processing on sensory acceptability scores.

Product type	Raw (mean ± SD)	Processed (mean ± SD)	Mean difference	t	p	Cohen's d
Pumpkin-based	2.81 ± 0.74	3.64 ± 0.68	0.83	6.92	<0.001	0.35
OFSP-based	2.93 ± 0.71	3.71 ± 0.65	0.78	6.34	<0.001	0.32
Mango-based	3.02 ± 0.69	3.85 ± 0.62	0.83	7.15	<0.001	0.37

Scores are from the paired raw-versus-processed hedonic comparison. Paired-sample t-tests; effect sizes reported as Cohen's d.

Determinants of Adoption

Six of the seven factors entered into the multivariable logistic regression were independently associated with adoption of processed underutilized products (Table 4). Exposure to nutrition education carried the strongest association (AOR = 1.74; 95% CI: 1.28–2.36; $p < 0.001$), followed closely by sensory acceptability (AOR = 1.68; 1.34–2.11; $p < 0.001$). Cultural food preference was next (AOR = 1.53; 1.19–1.96; $p = 0.001$), then perceived shelf-life benefit (AOR = 1.42; 1.11–1.82; $p = 0.005$), female household headship (AOR = 1.36; 1.01–1.83; $p = 0.043$), and household income level (AOR = 1.29; 1.03–1.62; $p = 0.027$).

District of residence was the single non-significant term (AOR = 1.12; 0.84–1.50; $p = 0.441$), its confidence interval crossing unity. Every significant predictor had a confidence interval lying entirely above 1.0, and all point estimates were positive, indicating that no measured factor operated as an independent deterrent to adoption. The spread of effect sizes was moderate rather than extreme, from 1.29 to 1.74, which suggests that adoption is driven by the accumulation of several enabling conditions rather than by any single decisive one.

Table 4: Multivariable logistic regression of factors influencing adoption of processed underutilized products (n = 400).

Predictor	Adjusted odds ratio (AOR)	95% CI	p-value
Nutrition education exposure	1.74	1.28–2.36	<0.001
Sensory acceptability score	1.68	1.34–2.11	<0.001
Cultural food preference	1.53	1.19–1.96	0.001
Perceived shelf-life benefit	1.42	1.11–1.82	0.005
Female-headed household	1.36	1.01–1.83	0.043
Household income level	1.29	1.03–1.62	0.027
District (Bombali)	1.12	0.84–1.50	0.441

Odds ratios are adjusted for all other variables in the model. Predictors are ordered by effect magnitude. An AOR above 1.0 with a confidence interval excluding 1.0 indicates an independent positive association with adoption. Tonkolili is the reference category for district.

Qualitative Accounts of What Enables and Constrains Use

Focus group and key-informant data explained the regression results and added the dimension the model could not capture — what sustains use once it has begun. Seven themes recurred.

Dietary Hierarchy: Participants consistently placed the three species outside the core of the meal. Rice anchored the diet both practically and culturally, and mango, OFSP, and pumpkin were framed as supporting foods. As one participant put it, rice is what households depend on and the others simply support it. This positioning meant that the species were used when convenient rather than when nutritionally indicated.

Narrow Culinary Repertoire: Households described knowing only one or two ways to prepare each species: mango eaten fresh, OFSP boiled or roasted, pumpkin added to soup. Several participants attributed this directly to inherited practice, saying they cook these foods the way they learned from their mothers. Others volunteered that they would use them more, particularly mango, if taught additional methods. This maps directly onto the nutrition education finding.

Knowledge of Benefit is Real but Uneven: Perceived health benefit was widespread but experiential rather than technical, OFSP was described as making children strong, pumpkin as building blood, mango as giving energy. Participants noted that those who understood the value would give these foods to children while others did not see the importance, indicating that the knowledge gradient within communities is itself a driver of differential uptake.

Supply Reliability, not Just Supply: Seasonality was raised most forcefully for mango, which participants described as overwhelming during its season and entirely absent afterwards. OFSP and pumpkin were considered steadier but still dependent on harvest conditions and, in the case of OFSP, on access to planting vines. Households with limited income depended almost entirely on their own production, since these species are not reliably purchasable off-season.

Equipment and Skills: Interest in processing exceeded capacity to do it. Participants expressed a clear wish to preserve mango so that it would last longer but said they did not know how to do it well, and lacked the necessary equipment. Key informants confirmed that training and support at household level are largely absent, and that processed forms of these products are rarely seen in local markets.

Women's Authority and Women's Time: Women were identified without exception as the decision-makers on what is cooked and how, and therefore as the effective gatekeepers of adoption; participants observed that if the woman does not prepare it, no one will eat it. The same participants identified time as the binding constraint, describing a wish to use these foods more often against the reality of competing responsibilities.

Social Learning: Adoption was described as spreading by observation rather than instruction. Participants explained that when one household begins using something and others see that it works, they try it too. This peer-visibility mechanism is not captured by any variable in the regression model but was raised repeatedly as the way practices take hold and persist.

DISCUSSION

This study set out to identify what determines whether rural households take up and keep using nutrition interventions built on underutilized species. The results support six of the seven hypotheses and, taken together, point to a consistent conclusion: adoption in this setting is governed by knowledge, experience, and household capability rather than by the physical availability of the foods themselves.

Knowledge is the Strongest Single Lever

Nutrition education exposure carried the largest adjusted association with adoption (AOR = 1.74). This is a consequential finding, because it locates the binding constraint on the demand side rather than the supply side. Households in these districts are not short of mango, pumpkin, or OFSP; what they lack is the practical and conceptual knowledge that converts availability into routine use. The qualitative data specify what kind of knowledge matters. Participants did not describe ignorance of whether these foods are good — perceived benefit was near-universal — but rather a narrow repertoire of what can be done with them. The gap is procedural rather than motivational. This distinction has direct programmatic implications: awareness campaigns that repeat the message that OFSP is good for children are unlikely to add much to what households already believe, whereas demonstrations of how to dry mango, blend a purée, or store a processed product address the constraint people actually described. The finding is consistent with evidence that homestead food production programmes achieve nutritional impact when combined with behaviour change communication rather than production support alone (Olney et al., 2021; Ruel et al., 2018).

Acceptability is the Behavioural Gateway

Sensory acceptability was the second strongest predictor (AOR = 1.68), and the paired comparisons show that processing moved acceptability substantially in every product category. Read together, these two results describe a mechanism: processing raises acceptability, and acceptability raises the odds of adoption. This is the practical justification for treating sensory evaluation as part of intervention design rather than as a downstream quality check. Foods perceived as unpalatable or inconvenient are not consumed regularly regardless of nutrient density (Turner et al., 2020; Fanzo et al., 2021), and the pumpkin–mango purée developed in this study illustrates the design logic that follows — mango supplying familiarity and sweetness, pumpkin supplying provitamin A density. The higher willingness-to-consume figure for mango juice (78%) than for the purée (64%) suggests that the closer a product sits to an already-familiar food form, the lower the behavioural threshold it must cross.

Cultural Fit Works as an Asset Here, Not an Obstacle

Cultural food preference was independently associated with adoption (AOR = 1.53). Much of the literature on underutilized species treats culture as a barrier, emphasising the stigmatisation of indigenous foods as markers of poverty or backwardness (Padulosi et al., 2016; Pingali, 2015; HLPE, 2020). That framing does not fit these findings. Mango, OFSP, and pumpkin are already familiar, already trusted, and already associated with health in participants' own accounts. The cultural obstacle identified here is narrower and more tractable: not rejection of the foods, but the entrenched position of rice at the centre of the meal, which relegates these species to a supporting role. Interventions therefore do not need to overcome hostility; they need to shift a food from the periphery of the meal towards its centre, which is a different and probably easier task.

Perceived Shelf-Life Links Processing to Sustained Use

Perceived shelf-life benefit predicted adoption independently (AOR = 1.42), which is notable because it is a perception rather than a measured property. Households that recognised the storage advantage of processing were more likely to adopt, whether or not they had measured it. Given that the companion analysis found a greater than tenfold extension in actual shelf life, the implication is that making this benefit visible through demonstration and side-by-side

storage comparison may itself increase uptake. Shelf life is also the mechanism by which adoption becomes sustainable rather than seasonal. Mango illustrates the point: without preservation its nutritional contribution is confined to a short window each year, and the practice of consuming it necessarily lapses when the season ends. Processing decouples consumption from the harvest calendar, which is a precondition for any behaviour that must persist across a full year (Jones et al., 2018; FAO, 2018).

Household Resources and the Gender Finding

Income level showed the smallest significant association (AOR = 1.29). Its modest size is itself informative: these are locally grown foods, and processing methods that require no specialised equipment reduce the extent to which uptake depends on purchasing power. The intervention is comparatively equity-neutral, which matters where the target population is disproportionately poor. Female household headship was associated with higher odds of adoption (AOR = 1.36). This aligns with the qualitative finding that women are the effective decision-makers over food preparation and with a substantial literature linking women's control of resources to improved dietary diversity and child nutrition (Njuki et al., 2016; Malapit et al., 2019; Ruel et al., 2018). The likely mechanism is decision latitude: where a woman heads the household, the person who decides what is cooked and the person who controls the resources are the same, removing a negotiation step. The estimate should be read with care; however its confidence interval approaches unity, headship was measured as a single binary indicator rather than through a validated empowerment scale, and female-headed households differ from male-headed households in ways this model does not capture.

The Null District Effect and What it Implies for Scaling

District of residence had no independent association with adoption once the behavioural and household factors were controlled. This null result is arguably as useful as the significant ones. It indicates that the differences between Bombali and Tonkolili; in agro-ecology, market access, and institutional presence, do not translate into differential adoption once knowledge, acceptability, cultural fit, shelf-life perception, and household resources are accounted for. The determinants of adoption are behavioural and household-level rather than geographic, which suggests that an intervention validated in one district can reasonably be expected to transfer to comparable districts without wholesale redesign. It also implies that targeting by district would be a weak allocation strategy compared with targeting by exposure to nutrition education or by processing capacity.

From Adoption to Sustainability

Adoption and sustainability are related but not identical, and the regression model speaks more directly to the first. The qualitative data carry most of the weight on the second, and they identify four conditions on which continued use depends. The first is reliable supply: households cannot sustain a practice for a food that disappears for months, which makes preservation and OFSP planting-material access structural rather than optional. The second is effort. Women repeatedly framed their constraint as time, not willingness, so any intervention that adds preparation labour is competing against an already binding limit; interventions that reduce effort are far more likely to persist than those that demand it. The third is visible benefit, since practices that do not produce noticeable results in children or in reduced waste are unlikely to survive the novelty period. The fourth is social reinforcement — participants described adoption spreading by observation, which argues for group-based and demonstration-led delivery over individual counselling.

These four conditions map cleanly onto the Sustainable Livelihoods Framework. Supply reliability is natural capital, processing skill is human capital, equipment is physical capital, income is financial capital, and peer learning networks are social capital. The pattern in the results is that human and social capital dominate: the two strongest predictors, nutrition education and acceptability, are both matters of knowledge and experience, while the financial term is the weakest of the significant predictors. This suggests that in this setting the assets that most constrain adoption are the ones that are cheapest to build. Read through Food Systems Theory, the finding reinforces the argument that utilization is a distinct node with its own determinants, and that production-focused interventions will not reach nutrition outcomes without addressing it (HLPE, 2017; Fanzo et al., 2021).

Limitations

Several limitations should be borne in mind. The cross-sectional design establishes association rather than causation, and reverse causality cannot be excluded — households already using processed products may seek out nutrition education rather than the reverse. Adoption was self-reported at a single time point rather than observed longitudinally, so the study measures reported uptake rather than durable behaviour, and stated willingness to consume is a weaker indicator than measured intake. Several predictors, notably cultural food preference and shelf-life perception, are perceptual measures whose construct validity rests on the survey instrument rather than on external validation. Female headship is a coarse proxy for women's decision-making authority, and a validated empowerment instrument would give a sharper estimate. Unmeasured confounders — including motivation, prior programme exposure, and household social connectedness — may account for part of the observed associations, and the social learning mechanism identified in the qualitative data is not represented in the model at all. Finally, the findings derive from two districts of one country and should be generalised to comparable rural West African settings with appropriate caution. These constraints define a clear agenda for longitudinal and, ideally, trial-based work on sustained adoption.

CONCLUSION

Underutilized species-based nutrition interventions succeed or fail on adoption, not on nutrient content. In Bombali and Tonkolili Districts, mango, OFSP, and pumpkin are widely available yet substantially underutilized, and the factors that separate households which adopt processed forms of these foods from those which do not are behavioural and capability-related: exposure to nutrition education, sensory acceptability, cultural fit, perceived shelf-life benefit, female household headship, and, least strongly, income. District of residence had no independent effect.

The practical reading is straightforward. Investment in practical, demonstration-led processing training is likely to yield more adoption per unit of resource than investment in supply expansion alone; products should be designed around what people find palatable and familiar rather than around nutrient content alone; the storage advantage of processing should be made visible rather than merely asserted; and delivery should be group-based and gender-aware, supporting women's workload rather than adding to it. Because the determinants are household-level rather than geographic, interventions validated in these districts can reasonably be expected to transfer to comparable settings. Longitudinal follow-up is needed to establish whether adoption measured at a single point in time endures, and to test whether the effort-reducing design principles identified here in fact predict persistence.

Declarations

Ethical Approval and Consent: Ethical approval was granted by the Njala University ethics review committee. Permission was obtained from district authorities and community leaders, and informed consent was obtained from all participants prior to data collection.

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Competing Interests: The authors declare no competing interests.

Data Availability: The datasets generated and analysed during this study are available from the corresponding author on reasonable request, subject to the confidentiality undertakings given to participants.

Authors' Contributions: All authors contributed to the conception and design of the study. The first author led data collection, analysis, and drafting of the manuscript. All authors reviewed, revised, and approved the final version.

Related Work: The processing, shelf-life, and vitamin A retention findings referred to in this paper are reported in full in a companion manuscript derived from the same study.

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