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Integrative review on the use of sensory evaluation methods in consumer-led product development for indigenous fruits and vegetables

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Indigenous Fruits and Vegetables (IFVs) are gaining renewed interest due to their nutritional richness, ecological resilience, and deep cultural value. Yet, they remain underutilized in formal food systems and product development. This integrative review synthesizes current literature and practical case studies to explore how consumer-led product development (CLPD) and sensory science tools can revitalize IFVs for modern markets. It presents an array of empirical approaches, including descriptive profiling, sensory lexicon development, consumer surveys, focus group discussions, conjoint analysis, and acceptance testing, demonstrating their application through selected case studies of *Chrysophyllum albidum* (commonly known as African star apple and locally referred to as Alasa), *Xanthosoma sagittifolium* (kontomire), *Averrhoa carambola* (star fruit) and mushrooms. The selected examples show how active consumer input enhances scientific rigor and ensures that the resulting food innovations are both nutritionally beneficial and culturally sensitive. The review discusses advantages, challenges, and key factors for successful CLPD implementation, such as management buy-in, robust methodologies, iterative development, and clear project objectives. By aligning product innovation with consumer preferences and engaging stakeholders throughout development, CLPD emerges as a powerful, evidence-based strategy to place IFVs within modern food systems. The paper concludes with recommendations on expanding CLPD for IFV-based food innovation, emphasizing participatory approaches to reflect the heritage and evolving needs of today's global consumer.

KEYWORDS

consumer-led product development, food systems, Ghana, indigenous fruit and vegetables, sensory evaluation

1 Introduction

Indigenous Fruits and Vegetables (IFVs), as referred to in this paper, are plant species that are native to a specific region and have traditionally been cultivated and consumed by local communities over generations. IFVs have received increasing interest within food systems research due to their nutritional, ecological, and cultural significance, promising to diversify global food systems that are often dominated by a few staple crops (Kehinde et al., 2023; Smith and Eyzaguirre, 2007). The shift toward healthier, sustainable, and culturally authentic food choices is desired by modern consumers, who seek foods rich in micronutrients and beneficial phytochemicals while being mindful of environmental and cultural impacts (Enriquez and Archila-Godinez, 2022; Marty et al., 2022). IFVs, being locally adapted and deeply rooted in tradition, present an opportunity to improve dietary quality, enhance agro-biodiversity, and foster food sovereignty (Hunter et al., 2016; Padulosi et al., 2013).

Despite their recognized benefits, such as high levels of provitamin A, iron, calcium, antioxidants (Frison et al., 2006; Mabhaudhi et al., 2019), and environmental adaptability (FAO, 2019), IFVs remain underutilized in formal product development. Key barriers include limited research, minimal processing infrastructure, low market visibility, and prevailing perceptions associating these products with rural food insecurity (Mabhaudhi et al., 2017; Kehinde et al., 2023). Rapid urbanization and globalization have further led to the marginalization of IFVs, erosion of traditional knowledge, and loss of dietary diversity, with negative implications for health and heritage (Johns and Sthapit, 2004). Currently, much work is focused on finding ways to incorporate IFVs into global food system and food product development is one way to achieve this.

Within the food system, consumer-led product development (CLPD) offers a strategic route to integrate indigenous knowledge into the product development process. Introduced in the early twentieth century, it has since become central to new product development within the food industry (Costa and Jongen, 2006) as it positions consumer needs as the foundation of innovation, emphasizing market relevance over technological advancement.

Sensory analysis provides one of the most robust tools set for implementing the development process within the CLPD approach. Growing evidence suggests that utilising sensory and consumer science tools can effectively drive innovation and market acceptance of indigenous fruits and vegetables (IFVs). Sensory analysis tools used within the CLPD approach provide an actionable framework for translating consumer insights into product attributes that align with sensory appeal, cultural relevance, and nutritional value: key factors in elevating IFVs from marginalized to mainstream food products. For instance, techniques such as descriptive profiling, hedonic testing, and consumer preference mapping help identify sensory drivers of liking (Lawless and Heymann, 2010; Jaeger and MacFie, 2010) which provide meaningful information to direct product development of IFVs using sensory cues that resonate with consumers.

When effectively implemented, CLPD remains a robust framework for aligning innovation design and communication. It also enhances market fit, facilitates co-creation, and increases the likelihood of product success (Costa et al., 2004). Recent studies highlight its growing relevance in sustainability-oriented innovation, where consumer participation supports eco-friendly product acceptance and fosters cross-disciplinary collaboration

(Sijtsema and Snoek, 2023; Mansilla-Obando et al., 2023). Building on these strengths, CLPD can serve as a strategic approach to revitalize the use of indigenous fruit and vegetable (IFV) products.

Notwithstanding, CLPD has been criticized for its methodological vagueness, high resource demands, (Falahat et al., 2024) dependence on shifting or unreliable consumer preferences that may not accurately predict purchasing behaviour (Alonso-García et al., 2020), ethical considerations (especially with vulnerable populations), and consumer unfamiliarity with novel ingredients (Günden et al., 2024). Additionally, high product failure rates and the perception that CLPD favours incremental rather than radical innovation, further challenge its effectiveness (Costa and Jongen, 2006; Menguc et al., 2014). Despite these constraints, CLPD offers clear advantages: increased likelihood of market success, stronger consumer trust, and a pathway for restoring biodiversity and local identity via IFVs (Costa and Jongen, 2006; Guiné et al., 2020; Günden et al., 2024).

In this review we examine how selected sensory analyses tools can be integrated into CLPD for IFVs. Specifically, we evaluate the advantages, challenges, and success factors of CLPD implementation, using empirical case studies to illustrate its application in enhancing consumer-driven innovation within the IFV sector.

Integrating some of these sensory and consumer analyses tools into the product development process provide a holistic and rigorous framework for CLPD, bridging technical formulation with culturally resonant and market-ready innovation.

2 Methodology

This integrated review combines published research on IFV development, sensory science, and consumer engagement with original case studies from the University of Ghana Sensory Evaluation Laboratory (UG-SenLab) in Ghana. Literature was selected for relevance to food product innovation using IFVs, sensory evaluation, and CLPD approaches.

2.1 Literature search and selection

A traditional literature search method was used initially to provide the scope of this review. The initial findings were strengthened with a comprehensive search for relevant literature conducted across Google Scholar, Scopus, and PubMed. Search terms were constructed using Boolean operators to capture key terms based on the initial scope narrowing down to find literature at the intersections between sensory science, consumer behaviour, and indigenous fruits and vegetables. Keywords included combinations such as: “indigenous fruits and vegetables” OR “neglected and underutilized fruits and vegetables” AND “sensory evaluation” OR “consumer testing” AND “product development” OR “food innovation,” as well as phrases like “indigenous fruits and vegetables,” “indigenous fruits and vegetables sensory evaluation,” “indigenous fruits and vegetables product development.” This search was done between November 6th and 11th 2025. The papers were selected based on the following criteria, the study focused on product development using indigenous fruits and vegetables and sensory evaluation was used in the product development. All selected studies comprised research papers written

in English and did not include any textbooks or papers written in different languages.

2.2 Data extraction and case study integration

Relevant information was extracted from the selected papers using a data charting sheet. Empirical case studies from the Sensory Laboratory at the University of Ghana were integrated to illustrate applied methods including consumer surveys ($n = 203$), sensory lexicon development using a trained sensory descriptive panel (56 descriptors for *Chrysophyllum albidum* (Alasa fruit)), descriptive profiling with and without focus group discussion (*Xanthosoma sagittifolium* (Kontomire) leaves) and conjoint analysis (*Azadirachta indica* (Neem) beverage). Each method was employed to gather both consumer perceptions and technical sensory data, integrated with cross-disciplinary insights from nutrition, marketing, and product development fields.

3 Results and discussion

3.1 Using sensory and consumer science as the backbone for product development

The success of any new food product hinges not only on its nutritional value or functional ingredients but also, critically, on how the consumer perceives it. Sensory and consumer science provides a systematic approach to understanding how people experience food through their senses and how these experiences drive consumption, preferences, choices, and ultimately, market acceptance (Lawless and Heymann, 2010). In the context of food innovation, particularly with underutilized ingredients such as Indigenous Fruits and Vegetables, sensory evaluation serves as both a creative and strategic tool for guiding product development (Jaeger and MacFie, 2010). Some commonly used sensory methods are briefly described below.

Although not limited to the field of sensory science, consumer surveys are a default sensory tool for understanding consumers in the development process. When used in sensory and consumer research, consumer surveys quantitatively assess awareness, consumption patterns, and preferences. In product development, consumer surveys help developers identify which IFVs are culturally embedded and favoured, as well as those that require repositioning and education for broader adoption (Horvat et al., 2019). For example, a Ghanaian survey showed high recognition for *Chrysophyllum albidum* (Alasa or African star apple), *Annona muricata* (Soursop) and *Dialium guineense* (Velvet tamarind), guiding their prioritization in product development (Addo-Preko et al., 2025). This example is expanded on as a case study further in the review.

Focus group discussions fall under qualitative consumer tests that provide rich consumer insights for the sensory scientist. A focus group discussion is a semi structured discussion with a small group of target users, guided by a moderator who keeps the conversation moving without steering it. The aim is to uncover attitudes, motivations, and insights that do not appear in surveys or other quantitative methods. Because the data are qualitative, the focus is on beliefs, personal experiences, and the meaning people attach to products. Participant

interaction often surfaces subtle issues such as emotional ties, lifestyle influences, and quiet expectations that shape strong product ideas. Focus group discussion support early new product development by revealing unmet needs before concept generation, providing reactions to early designs, and offering feedback on refined concepts. They fit well within iterative design because hearing users think aloud builds empathy and sharpens decisions. In food product development, early sessions uncover sensory expectations and cooking habits, while later sessions test packaging or presentation, helping designers avoid mistakes and shape a clear product identity (McDonagh-Philp and Bruseberg, 2000). In the IFV realm, focus group discussions have been used to understand consumers beliefs about mushrooms when this was selected as an ingredient to develop baby food. The discussion revealed cultural elements that guided developers on how to integrate the ingredient into the target group (Hagan et al., 2018).

Aside the consumer centric methods described above, analytical sensory methods are also important in the product development process. Within this group of tests, lexicons form the foundation for quantitatively analysing sensory properties of products. A lexicon is a standardized list of sensory terminology generated by trained assessors. When used on its own, this list enables development teams to communicate clear and objective sensory attributes across the formulation and marketing pipeline (Suwonsichon, 2019). It is especially valuable for IFVs given their novel, diverse and complex sensory profiles, which are not well known to the general consumer. In a case study example provided further in this review a comprehensive lexicon of 56 descriptors was created and used for reproducible sensory evaluation and product differentiation for *Chrysophyllum albidum* (Alasa) (Tagoe et al., 2025). Lexicons can further be used to quantitatively characterize products when scored in descriptive profiling of products.

A commonly used descriptive profile method is the Quantitative Descriptive Analysis (QDA) technique (Lawless and Heymann, 2010). Generally descriptive profiling methods use trained panels to conduct detailed characterization and scoring of product attributes, from, appearance, aroma and flavour to aftertaste. Descriptive profiles allow for the mapping of sensory drivers of liking when linked with consumer preferences (de Souza et al., 2024). On their own, descriptive profiles provide in depth elucidation of the sensory properties of IFVs and can be used to track sensory changes of these IFVs as they are processed. A case study with on leafy greens highlights the value of descriptive profile for tracking the changes in sensory properties as they are processed using different processes (Aboagye et al., 2025b).

Conjoint analysis (Green et al., 2001), borrowed from marketing, has gained favour in the sensory scientists toolbox as it provides a meaningful way to identify relevant sensory and consumer attributes that are favoured in a product by consumers. It is a statistical technique that uncovers how consumers make trade-offs among multiple product features, revealing which combinations drive preference and purchase intent (Hoppert et al., 2012; Green et al., 2001). The method was used to determine optimal levels of key sensory attributes; bitterness, aftertaste, and ingredient profiles in a neem beverage case study (Aboagye et al., 2025a).

These methods are not the only tools available to the sensory scientist that wishes to incorporate sensory insights into the CLPD approach. They however provide meaningful illustrations on using sensory and consumer science insights in the product development process.

3.2 Overview of consumer-led approach in food product development

A consumer-led product development approach places consumer needs and preferences at the centre of the product development process (Costa and Jongen, 2006). Rather than assuming what the market wants, this method emphasizes active engagement with target consumers at various stages of development from idea generation to prototype testing. Unlike traditional product development that may rely solely on expert input or technical feasibility, CLPD ensures that innovations are rooted in consumer realities and desires. This is particularly relevant when working with IFVs, where consumer knowledge, familiarity, and cultural relevance are pivotal to acceptance (Kehinde et al., 2023). By involving consumers early, food developers can (1) Align product concepts with market demands, (2) Enhance satisfaction by producing tailored offerings, (3) Reduce the risk of product failure, and (4) Drive innovation by identifying unmet needs (Guiné et al., 2020; Linnemann et al., 2006).

These researchers assert that consumer participatory approach not only increase the likelihood of market success but also ensures more efficient resource allocation by minimizing investment in concepts that do not resonate with end users (Falahat et al., 2024). CLPD can enhance market readiness, cultural resonance, and consumer acceptance. It however, requires dedicated resources, ethical engagement, and ongoing iterative refinement. As consumer preferences can shift; integration with regulatory and nutritional frameworks remains crucial while using CLPD.

3.3 Tools used in a consumer-led product development approach

A variety of sensory and consumer research tools (surveys, focus groups and interviews, lexicon development and descriptive profiling, conjoint analysis and acceptance tests) are available to capture insights that can inform IFV product development.

3.3.1 Using surveys to guide consumer-led product development

A consumer survey is an essential tool in CLPD. Surveys provide a structured means of collecting direct feedback from target populations, allowing product developers to assess not only preferences but also awareness, familiarity, and usage behaviours. Surveys are especially valuable during the early phases of product development, where foundational knowledge about consumer perceptions, needs, and cultural associations can shape strategic decisions. They offer a relatively low-cost and scalable method for gathering input across diverse demographics and regions, and they help contextualize other sensory and technical findings within real-world consumer behaviour (Horvat et al., 2019). In the context of IFVs, surveys can serve as a starting point for identifying which fruits and vegetables resonate with consumers, and which require further promotion or product adaptation. Further, surveys are useful to help with consumer segmentation and an understanding of population trends and consumption patterns.

Dashu et al. (2024) illustrate the role of surveys in understanding contemporary use and perception of Indigenous Green Leafy Vegetables (IGLVs). Their study focused on four commonly used

species; *Moringa oleifera*, *Cucurbita pepo* (pumpkin leaf), *Vernonia amygdalina* (bitter leaf), and *Amaranthus chlorostachys* (spinach) and explored their application in the preparation of local dishes, associated health beliefs, and the acceptability of newly developed recipes. Ten recipes were created, spanning stews, soups, salads, beverages, pastries, and sauces. A self-developed questionnaire was administered to 40 randomly selected individuals to assess perceptions and usage. Survey results confirmed that, among 10 IGLVs identified in the broader food system, the four selected were the most widely used, with stews (42.5%) and soups (32.5%) emerging as the dominant preparation methods. Although the sample size was modest, the survey effectively mapped consumer practices and guided the identification of recipe formats most likely to support increased IGLV consumption.

Gido et al. (2017) used surveys in a different but complementary way, focusing on consumer acceptance of fresh and cooked African Indigenous Vegetables (AIVs) as they are traditionally consumed. Unlike studies that introduce new or value-added products, this research aimed to understand existing consumption behaviour and the sociodemographic and perceptual factors shaping acceptance. Data were collected through interviewer-administered surveys at retail outlets, using a pre-tested semi-structured questionnaire. The analysis employed a Multivariate Probit (MVP) model to examine acceptance determinants for six AIVs simultaneously, allowing the researchers to account for correlations between vegetables in household decision-making.

Although no formal consumer acceptance testing was conducted, the study incorporated sensory-related perception variables such as taste, quality, and other product attributes as explanatory factors. These perceptions functioned as indirect sensory indicators, reflecting consumer beliefs rather than measured sensory properties. The findings therefore provide insights into how consumers conceptualize the sensory and quality attributes of IFVs, even though they do not constitute objective sensory profiling.

Together, these studies highlight the strategic role of surveys in CLPD for IFVs. They map the terrain of consumer familiarity, reveal culturally preferred preparation methods, and pinpoint the perceptual attributes that either support or hinder acceptance. When integrated with consumer acceptance testing and product development, survey data enrich the understanding of consumer behaviour and help shape IFV innovations that are not only technically feasible but also socially and culturally aligned.

3.3.2 Case study 1: understanding indigenous fruit preferences: a case from Ghana

To illustrate the application of surveys in product development, a study by the University of Ghana Sensory Evaluation Laboratory (UGSENLAB) was conducted to gather insights on Ghanaian consumers' awareness, consumption, and preferences for indigenous fruits (Addo-Preko et al., 2025). The survey was administered online using a structured questionnaire hosted on Google Forms. The questionnaire contained pictures and names of different fruits found in Ghana. This was to help participants identify the fruits even if they did not know the name. A total of 203 participants filled the questionnaire. The questionnaire collected data on demographics, fruit familiarity, consumption patterns, and preference rankings.

From the survey, majority of respondents were aged between 25 and 34 years, suggesting a younger, potentially trend-aware

demographic. Awareness of fruits such as African star apple (Alasa), Velvet tamarind (Yooyi), Soursop, and (*Psidium guajava*) Guava exceeded 90%, indicating that these fruits remain culturally embedded and widely recognized. Conversely, Baobab and Star fruit had much lower recognition.

Consumption patterns closely mirrored awareness levels. African star apple (Alasa), Yooyi and Soursop exhibited high consumption rates (82.3% and above). In contrast, Star fruit, Baobab and Sugar apple were consumed less frequently, suggesting that accessibility, familiarity, or taste preferences may limit their integration into everyday diets. When asked to select their most favourite fruit, Soursop, Velvet tamarind and African star apple ranked highest corroborating the importance of familiarity and habitual consumption in shaping consumer preference. Fruits such as (*Adansonia digitata*) Baobab and Star fruit received less than 2% of the vote.

The findings of this survey offer valuable guidance for product developers working with IFVs. Fruits like African star apple (Alasa), Yooyi, and Soursop are strong candidates for incorporation into value-added products such as juices, snacks, plant-based beverages, and functional desserts due to their high levels of consumer familiarity and preference. In contrast, underutilized fruits like Baobab and Star fruit, while nutritionally promising, may require greater investment in consumer education, repositioning, and product innovation to increase their appeal and market penetration.

This survey demonstrates how simple, yet structured consumer research can provide crucial insights into the opportunities and barriers surrounding the use of indigenous fruits in product development. By identifying the fruits that consumers know, eat, and love, food developers can make informed decisions about which ingredients to prioritize, how to position them, and how to design products that are both nutritionally meaningful and culturally relevant. When integrated with tools like descriptive profiling and conjoint analysis, surveys complete the feedback loop needed for a holistic, consumer-led approach to food innovation. Focus groups and interviews on the other hand allow deeper exploration of perceptions, motivations, and cultural associations around IFVs.

3.3.3 Developing sensory lexicons as a tool in consumer-led product development

An important but often overlooked tool in consumer-led product development (CLPD) is the sensory lexicon, a standardized vocabulary used to describe sensory attributes in clear and consistent terms. While consumer surveys and profiling techniques reveal preferences and intensities, lexicons supply the language needed to structure, communicate, and reproduce sensory insights. They act as a foundation for subsequent sensory evaluation, product design, quality assurance, and marketing (Suwonsichon, 2019). This tool is particularly valuable for underutilized indigenous fruits and vegetables (IFVs), many of which are familiar within local communities yet lack scientific documentation of their sensory characteristics. One such example is the African star apple (Alasa) in Ghana, a culturally significant fruit with little formal sensory description.

Evidence from the broader literature illustrates how lexicon development strengthens CLPD by translating subjective perceptions into standardized, actionable knowledge. Smyth et al. (2012) demonstrated this clearly in their creation of an Australian Native Flavour Wheel, producing a concise lexicon for 16 native fruits and herbs. Through descriptive profiling, the researchers generated

quantitative sensory signatures, such as “rosella” notes in Davidson plum or “lemon candy” aroma in lemon myrtle, thereby establishing a common language for industry, chefs, and product developers. This standardized vocabulary facilitated market communication, ingredient promotion, and consistent quality control, showing how lexicons can help elevate unfamiliar species into broader commercial use.

Similar value is seen in Semuli (2014) work on *Agave americana* flowers. A trained panel developed a 21-term lexicon that differentiated aroma, taste, texture, and aftertaste attributes across various processing treatments. The lexicon allowed researchers to separate desirable traits, such as sweet–sour flavours and nutty aromas from undesirable ones like bitterness or fibrous textures. This guided critical product development decisions, including selecting blanched flowers for steamed bread to minimize bitterness, or using unblanched flour in chocolate cake where bitterness could complement cocoa. By linking processing methods to sensory outcomes through a structured vocabulary, the study optimized ingredient selection, pre-treatment steps, and product formulation.

Lexicon development has also supported consumer-driven improvements in African leafy vegetables (Onyeoziri et al., 2018). A standardized set of 21 attributes enabled objective comparison across species and canning media, revealing sensory drivers of liking, such as buttery, sweet, or popcorn-like notes and identifying attributes contributing to rejection, including bitterness, astringency, or metallic flavours. These insights informed targeted reformulation strategies, highlighted processing challenges, and strengthened product communication for commercialization.

Across these studies, sensory lexicons emerge as practical, evidence-based tools that bridge scientific analysis and consumer relevance. For IFVs, they offer a pathway to transform culturally familiar but scientifically undocumented foods into products that can be systematically evaluated, optimized, and brought into broader markets.

3.3.4 Case study 2: sensory lexicon development for Alasa (African star apple—*Chrysophyllum albidum*)

The aim of the sensory lexicon development was to capture and organize the descriptive terms that describe Alasa sourced from different locations to highlight its diversity. This involved a trained panel at UG-SENLAB describing different Alasa samples purchased from different locations in Accra, Ghana (Tague et al., 2025).

The lexicon containing 56 descriptors across six sensory dimensions (appearance, aroma, flavour, texture, and aftertaste). This approach facilitates product optimization, addressing market and cultural needs as well as providing actionable guidance for development teams on relevant sensory properties. In the study, common visual descriptors for the outer part included colour and appearance properties like *orange colour*, *firm*, *glossy*, *black spots*, and *fibrous*. The inner flesh was described as *juicy* and *creamy* for most of the samples, while the seed was associated with attributes like *dark brown*, *smooth*, and *hard*. Aromatic descriptors featured terms such as *sweet smell*, *guava*, and a unique “Alasa-like” note, an indication of the fruit’s distinctive indigenous character. The flavour profile included *sweet*, *sour*, *bitter*, and *Alasa*, with the skin typically *bitter* and the flesh exhibiting a *sweet–sour* balance. Notably, terms like “Alasa” and “guava” point to tropical aroma notes.

Textural terms included *moist*, *sticky*, and *firm* (texture-in-hand) and *chewy*, *juicy*, *smooth*, *gum-like*, *astringent*, and *puckering* (mouthfeel), reflecting the fruit's complex tactile profile. Aftertaste descriptors such as *coating*, *residue*, *sour*, and *bitter-sweet* revealed that lingering sensory effects are a defining part of the Alasa experience.

The Alasa sensory lexicon has implications for product development in that it provides a standardized vocabulary that can guide in the development of value-added products, from juices and dried fruit chews to snack bars and sauces. Descriptors such as chewy, fibrous, juicy, and astringent can guide decisions about product format, processing, and flavour enhancement. For example, the gum-like mouthfeel suggests potential applications in natural thickeners or fillings, while bitterness from the skin might need to be controlled through peeling or sweetener addition. The extensive number of attributes (56) of the Alasa as opposed to earlier examples with 21 words each, reflects the layered nature of the Alasa fruit, with specific terms developed to describe the skin, flesh and pith (seed) across the six modalities.

Moreover, the lexicon provides critical insight into important textural attributes that may affect consumer acceptance. Terms like adhesive, cohesive, and astringent highlight sensations that linger and influence liking, features that can either be enhanced or minimized depending on the product concept. For instance, products targeting children may emphasize sweetness and smooth mouthfeel, while those aimed at adult health-conscious consumers may retain mild bitterness and fibrous texture to emphasize naturalness.

The sensory lexicon developed for Alasa represents a foundational step in scientifically capturing the unique sensory attributes of a culturally significant but underutilized indigenous fruit. It enables more structured sensory evaluation, facilitates communication across product development teams, and supports innovation grounded in local identity. Importantly, it also lays the groundwork for developing standardized sensory profiles and training panels that can be used in both academic research and industry-level product development, further promoting the integration of indigenous biodiversity into modern food systems.

3.3.5 Descriptive profiling as a tool in consumer-led product development

Among the sensory tools available in consumer-led product development (CLPD), descriptive profiling, especially through Quantitative Descriptive Analysis (QDA), stands out as a key method for characterizing the detailed sensory attributes of food products. When carried out by trained panels, QDA generates a sensory blueprint capturing dimensions such as appearance, aroma, flavour, mouthfeel, and aftertaste. This makes it an indispensable link between technical formulation and consumer perception (De Pilli et al., 2024). In the context of IFVs, descriptive profiling helps developers not only to understand the unique sensory signatures of underutilized ingredients but also to translate consumer expectations into measurable product qualities.

Below are three ways QDA can be strategically applied in consumer-led product development:

1 Establishing a benchmark or reference framework

Descriptive profiling allows for the in-depth sensory characterization of existing or culturally accepted products. By

profiling market leaders, traditional preparations, or competitive items, developers can identify key attributes that define consumer preference within a category. Products can be compared across dimensions like sweetness, bitterness, crunchiness, astringency, or aroma complexity to set sensory targets that new products should meet or exceed. This ensures the product is developed in alignment with real-world expectations rather than theoretical formulations (Lawless and Heymann, 2010).

2 Translating consumer language into measurable sensory attributes

Consumers often describe food experiences in abstract or emotive terms such as “fresh,” “zesty,” or “natural.” Descriptive profiling bridges this gap by transforming such subjective expressions into quantitative sensory data. Through lexicon development, panellists and researchers establish agreed-upon definitions and reference standards for sensory terms derived from consumer feedback. This facilitates clear communication across product development teams and helps ensure that product prototypes reflect the qualities that consumers truly value (Ruiz-Capillas et al., 2021).

3 Understanding the sensory effects of processing on raw ingredients

In IFV-based product development, it is vital to understand how the processing of raw ingredients influences their sensory attributes. Descriptive profiling can be applied across multiple stages evaluating ingredients in both raw and processed forms to capture how sensory qualities evolve through techniques like drying, boiling, fermentation, or extrusion (dos Santos Rocha et al., 2022; Araya et al., 2009). This helps identify processing methods that preserve desirable traits, reduce off-notes, and align with consumer preferences.

Several studies demonstrate how sensory profiling tools, particularly, Quantitative Descriptive Analysis (QDA) and Descriptive Sensory Analysis (DSA), provide the rigorous, structured insights needed to guide IFV product development within the three-fold benefits earlier alluded to. Pande et al. (2025) compared microwave blanching (MWB) and conventional hot-water blanching (CHWB) of star fruit to determine how pre-processing influenced flavour, aroma, colour, and texture. Using QDA with a trained 12-member panel, the authors showed that MWB better preserved fresh-like attributes and minimized heat-induced defects such as cooked aromas and browning. This confirmed that sensory analysis, can objectively validate processing technologies that enhance both nutritional and sensory quality in underutilized fruits.

A similar approach was taken by Kengni et al. (2017) in their evaluation of tropical bush mango (*Irvingia gabonensis*). Through QDA on fresh pulp and processed kernels, the researchers were able to differentiate cultivars and identify processing methods that maintained desirable sensory characteristics. Their findings provided the first quantitative standards for sensory quality in this species, supporting breeding decisions and the establishment of quality benchmarks; two essential components for scaling IFV value chains.

Work on indigenous durian species by Belgis et al. (2016) further illustrates how descriptive profiling bridges sensory perception with instrumental measurements to support objective measurement of critical attributes in product development. Using

a 15-cm line scale, trained panellists characterized sweetness, sourness, bitterness, and texture attributes of multiple cultivars. The strong correspondence between sensory profiles and physicochemical data demonstrated that instrumental measures can reliably predict human perception when validated against QDA, a critical insight for designing IFV products with consistent quality.

Other studies have used sensory analysis to characterize commercially relevant IFVs. Al-Farsi et al. (2005) applied descriptive profiling to three sun-dried date varieties, generating quantitative sensory signatures that helped explain existing commercial classifications and their links to compositional attributes such as sugar and organic acid content. Likewise, Onyeoziri et al. (2018) used DSA to profile canned African leafy vegetables. By linking sensory profiles to consumer liking through multivariate analysis, the authors identified the specific sensory drivers of preference, information that directly supports targeted reformulation and product positioning.

Finally, sensory profiling has been applied directly to IFV product innovation. Semuli (2014) used DSA to optimize processing methods for *Agave americana* flowers, identifying blanching as essential for reducing bitterness and improving texture. Zhu et al. (2014) similarly used QDA to guide the development of persimmon fruit wine, connecting sensory harmony and fruitiness to specific yeast strains.

Collectively, these studies demonstrate that descriptive sensory analysis is indispensable not only for characterizing IFVs but also for guiding processing choices, optimizing product formats, and establishing the sensory foundations needed for successful CLPD-driven innovation that give consistent quality, especially when linked with instrumental data.

3.3.6 Case study 3: profiling *Xanthosoma sagittifolium* (Kontomire/ cocoyam leaves)

A study at UG-SENLAB evaluated the impact of processing on the sensory characteristics of kontomire an indigenous green leafy vegetable in Ghana, using QDA (Aboagye et al., 2025b). Fresh, blanched, and boiled samples were assessed by a trained panel to understand how sensory modalities changed.

The appearance of the fresh kontomire leaves were described as deep forest green. Blanching lightened the green colour intensity, while boiling changed the hue from forest green to olive-green hue. Furthermore, processing introduced new attributes such as juiciness, sogginess, and translucency reflecting the cooking method (boiling) that had been applied.

The aroma of the fresh kontomire leaves had grassy, watermelon rind, sugarcane, unripe pawpaw, and plantain leaf notes. These were replaced post-processing by attributes such as seashore, boiled maize, metallic, and fresh clam notes. Although similar attributes were retained in the blanched and boiled forms, the intensities varied as was observed with the aroma note, described as *boiled yam aroma*. The intensity was higher in the blanched samples than boiled ones.

As expected, the texture of the blanched and boiled leaves was softer and more delicate than the fresh leaves.

This case revealed how processing alters both the intensity and the nature of key attributes. It can guide formulation choices to either preserve fresh-like characteristics or enhance new, appealing notes. This type of sensory map is especially useful when working with underutilized or unfamiliar ingredients, providing a scientific foundation for optimizing product acceptability.

Ultimately, descriptive analyses offer a scientific yet consumer-focused lens through which food products particularly those involving IFVs can be crafted to be both innovative and culturally resonant.

3.4 Consumer acceptance testing in consumer-led product development

Consumer acceptance testing sits at the heart of consumer-led product development (CLPD), particularly when the goal is to transform indigenous fruits and vegetables (IFVs) into appealing, culturally grounded, and commercially viable foods. Unlike descriptive sensory analysis, where trained panels generate objective profiles of appearance, aroma, taste, and texture, consumer testing requires large numbers of naïve consumers who represent the actual target market. In sensory science, a minimum of 112 consumers is considered essential for reliable, generalizable results (Hough et al., 2006), and trained or semi-trained panels are never an appropriate substitute for consumer acceptance testing. Across the IFV literature, however, practices vary widely. While some studies follow established standards, others rely on small, semi-trained groups whose assessments cannot reliably predict real-world liking. This review synthesizes the evidence from numerous IFV studies, evaluating both their sensory findings and the methodological rigour behind them, to illustrate how consumer insight, when gathered correctly, can drive innovation, reformulation, and the broader revitalization of indigenous crops.

The strongest examples of consumer-appropriate methodology come from studies that employ large samples of naïve participants. Mbhatsani et al. (2023) provides a model aligned with CLPD by evaluating school-meal dishes incorporating *Amaranthus*, cowpea leaves, and *Bidens pilosa* using 152 primary-school children. This sample size enhances statistical confidence, and the use of the target consumers, children, ensures the validity of the findings. The study not only identified the most acceptable dish (*Amaranthus*-enriched cabbage) but also linked hedonic ratings with actual consumption. This integration of sensory testing with behavioural outcomes exemplifies how consumer data can guide product optimization, menu planning, and intervention design.

Likewise, Schiassi et al. (2018) evaluated pulps from four Cerrado fruits with 100 adult consumers and identified key sensory drivers for their use in functional beverages. Here too, the choice of appropriate panellists and sample size strengthens the study's conclusions.

and demonstrates how IFVs can successfully compete in commercial beverage categories. But many IFV studies use designs that diverge from best practice. Several rely on trained or semi-trained individuals, a practice that introduces conceptual and statistical limitations. Trained assessors are experts in detecting subtle differences; they do not represent ordinary consumers and therefore cannot provide meaningful measures of liking or purchase intent. Semi-trained individuals, often laboratory staff or students familiar with sensory evaluation, occupy an ambiguous middle zone that still fails to reflect consumer preferences. Studies with small samples, 15, 10, even nine panellists, further limit generalizability. As a result, many reported findings must be interpreted as preliminary rather than indicative of market potential. Adedokun et al. (2022), for example, evaluated juice blends of baobab, black plum, and pineapple using only 15 semi-trained laboratory staff. While the study provides

insight into attribute differences such as mouthfeel and flavour intensity, these judgments cannot be extrapolated to consumer liking. Similarly, wine formulations from *Balanites aegyptiaca* (Bayoï and Etoa, 2024) were assessed by just 10 wine consumers. Although these individuals may have some product familiarity, the small sample size still prevents any meaningful inference about broader market appeal. The trend continues in Qureshi et al. (2024), where paneer enriched with date paste was evaluated by 10 semi-trained panelists; in Meti (2018), where *Basella alba* products were scored by nine assessors; in Pradhan et al. (2020), where ash-gourd products were evaluated by 10 trained panelists; and in Suliman et al. (2012), where just 15 panelists assessed jakjak juice. These studies contribute valuable prototype-level insights, but they cannot answer the fundamental consumer-led question: Will people like it? Other studies fall closer to acceptable standards yet still contain methodological pitfalls. Goyary et al. (2022) used 50 panelists, an appropriate number, but mixed trained and untrained individuals, which introduces bias because trained assessors evaluate differently from naïve consumers. Kumari et al. (2022) do not report sample size at all, a critical omission that undermines confidence in their findings. On the other hand, several studies provide robust examples of consumer-aligned testing that advance CLPD for IFVs. Tagubase et al. (2018) used 50 consumers to assess durian cultivars, employing both preference ranking and intensity perception. Samuel et al. (2020) evaluated a fruit-based soup from *Corchorus olitorius* with 30 consumers, slightly under ideal sample size, but still using the correct type of panel. Van der Hoeven et al. (2013) used 98 children to evaluate African leafy vegetable dishes, aligning both sample size and participant identity with the intended beneficiaries of school-feeding interventions. A large portion of IFV sensory literature combines consumer tests with descriptive analysis. This combined approach can reveal drivers of liking, bitterness, colour, texture, sweetness, and guide targeted formulation. For instance, Onyeoziri et al. (2018) integrated descriptive profiling with consumer testing of canned African leafy vegetables, identifying specific sensory attributes that limited acceptance. Such studies exemplify how lexicon-driven sensory insights complement CLPD by pinpointing attributes requiring modification. Multiple researchers have shown how indigenous fruits can be reformulated, blended, or processed to enhance acceptability. Jam development appears frequently across IFV studies and is a particularly illustrative example of how consumer feedback shapes product trajectories. Rafique et al. (2023) used a 9-point hedonic test to determine optimal karonda–apple jam ratios, while de Jager et al. (2025) used a two-step consumer protocol—first visual testing with nearly 100 consumers, then hedonic evaluation with 47—to identify preferred jam types.

These studies, though variable in sample size, underline how appearance and flavour jointly determine product acceptance. Functional or fortified products enriched with probiotics, antioxidants, or nutrient-dense IFV powders also demonstrate the balancing act between health benefit and palatability. Harriden et al. (2025) used sensory evaluation to determine the optimal inclusion level of Davidson plum in sorbet, finding that functional enhancement quickly becomes a sensory liability at high concentrations. Similarly, Micheni et al. (2024) showed that horned-melon supplementation in fermented milk decreased liking at high levels, particularly around colour and taste. Such formulations demonstrate how CLPD can reconcile nutritional goals with sensory feasibility.

Several studies focus on leafy vegetables, where bitterness, fibrousness, and colour changes often challenge consumer acceptance. Matenge et al. (2012) found that tomato-based cowpea leaf stew was more acceptable than other preparations, underscoring the importance of culinary context. Muniu (2020) demonstrated that solar drying reduces liking for some species but enhances it for others, showing how preservation interacts with sensory traits. Across beverages, jams, confectioneries, soups, porridges, pickles, and even chocolates fortified with IFV powders, sensory evaluation appears repeatedly as the guiding mechanism for product refinement. Some studies, such as those by Tepe (2022), go further by integrating consumer liking with economic models such as willingness-to-pay, demonstrating how sensory appeal directly predicts market behaviour. Yet the methodological weaknesses across much of the literature highlight the urgent need for improved standards. Studies using small, trained panels generate data that are more relevant for descriptive analysis than consumer acceptance. Mixing trained and untrained panellists produces inconsistent results. Failure to report sample sizes reduces replicability and credibility. In some cases, the absence of clear target consumer groups (e.g., children, adolescents, adults, specific cultural communities) further limits applicability.

For CLPD to meaningfully support the revitalization and commercialization of IFVs, sensory consumer studies must adhere to established principles: naïve consumers, adequate sample sizes, context-specific recruitment, and clear reporting. The studies reviewed demonstrate that when these standards are met, sensory consumer evaluation becomes a powerful engine for innovation. It identifies feasible formulations, clarifies optimal preparation methods, determines acceptability thresholds, and guides product-type selection. It also provides insights into storage stability, ingredient interactions, and the trade-offs between nutritional enhancement and palatability. Together, these studies show that consumer testing, when methodologically sound, anchors CLPD by positioning consumer perception at the centre of product development. IFVs often carry exceptional nutritional value but limited market penetration due to sensory unfamiliarity or stigma. Sensory evaluation provides the mechanism for transforming these culturally significant crops into appealing foods suited for modern markets, thereby linking biodiversity, nutrition, and consumer behaviour in a single integrative framework.

3.5 Using focus groups in consumer-led product development

Focus groups are a central qualitative tool in consumer-led product development (CLPD) because they generate rich, contextual insights into how people think, feel, and talk about foods. Unlike structured surveys, which capture breadth, focus groups capture depth, revealing cultural meanings, sensory expectations, preparation habits, and the social narratives that shape acceptance. They allow researchers to probe why certain attributes matter, how consumers interpret quality, and what barriers or motivations influence adoption. This qualitative foundation often guides early formulation choices and helps frame subsequent sensory or consumer testing within the lived realities of target populations.

Matenge et al. (2012) illustrate this approach through their work with Traditional Leafy Vegetables (TLVs), focusing on cowpea leaves

(*Vigna unguiculata* L.). The authors developed three recipe variations that reflect common preparation styles: cowpea leaves cooked with salt and vegetable oil (Sample A); a tomato-based stew with potatoes, onions, salt, and oil (Sample B); and a preparation incorporating groundnut powder (Sample C).

To understand consumer beliefs and contextual factors shaping acceptance, four focus group discussions were held across rural and urban communities. Thematic content analysis revealed perceptions related to taste expectations, cultural familiarity, preparation convenience, and the symbolic value of cowpea leaves in traditional diets. These insights helped clarify not only what people preferred but why those preferences existed.

Sensory evaluation was then used to complement the qualitative data by providing empirical, quantitative evidence of product acceptance. It revealed clear differences in preference patterns across age groups and communities and identified Sample B as the most promising formulation. The sensory findings also highlighted the pivotal role of taste and texture in shaping consumption intent.

By combining focus group insights with consumer acceptance testing, the study demonstrated how qualitative understanding, and quantitative testing can work together to guide CLPD. This integrated approach helps ensure that product concepts for Indigenous and Forgotten Vegetables (IFVs) are grounded in cultural relevance while meeting sensory expectations that drive actual consumer uptake.

3.6 Using conjoint analysis in consumer-led product development

While descriptive profiling offers a structured understanding of a product's sensory characteristics, conjoint analysis complements this by revealing the relative importance of those characteristics alongside other product attributes in shaping consumer choice. As a statistical technique rooted in behavioural science and marketing research, conjoint analysis is particularly valuable in CLPD. It allows researchers and product developers to understand how consumers make decisions when faced with products that differ across multiple features such as flavour, texture, packaging, ingredient sources, and health claims (Hoppert et al., 2012; Green et al., 2001).

Unlike methods that test one feature at a time, conjoint analysis mimics real-life decision-making, where consumers evaluate multiple product attributes simultaneously. In a typical study, participants are presented with a set of product profiles that vary systematically in their attribute combinations. These profiles can be introduced in various formats depending on the nature of the product and the development phase. For instance, actual product samples may be used when evaluating features like taste or texture (De Pelsmaeker et al., 2013). In other cases, especially during early development stages or when product prototypes are unavailable visual presentations such as packaging mock-ups or verbal descriptions of the attributes are used to convey the product concept. Consumers then rank, rate, or choose between the options, enabling researchers to model preference behaviour (Ares et al., 2016).

Through this process, conjoint analysis provides three major insights: the relative importance of each attribute in influencing consumer choice, the preferred levels within each attribute, and the optimal combination of features that define the most appealing product. These outcomes help product developers prioritize

formulation efforts, target consumer segments more precisely, and refine marketing strategies based on what truly matters to their audience (Moskowitz et al., 2012). Moreover, because conjoint analysis allows developers to simulate consumer preferences before investing in full-scale production, it offers a highly cost-effective tool for reducing risk during product innovation.

A relevant example comes from a study conducted at UGSENLAB, where conjoint analysis was applied in the development of a ready-to-drink neem beverage (Aboagye et al., 2025a). Neem, known for its strong medicinal properties and characteristically bitter flavour, presents formulation challenges when developing a beverage intended for broad consumer appeal. In this study, physical samples were not created. Instead, pictorial representations of the product, along with detailed verbal descriptions of the attributes, were shown to participants. The product concepts varied across key features such as bitterness intensity, aftertaste quality, authenticity, form of product, and the inclusion of added natural ingredients.

Participants were asked to rank the combinations from most liked to least liked, simulating a realistic decision-making scenario. The analysis revealed that bitterness, aftertaste, and ingredient addition were the most influential attributes in determining consumer preferences. The preferred product profile was clearly defined using this approach giving the developers the needed directions on which attributes were most important and relevant to maintain. The insights provided information on the form, the added ingredient and the sensory experience that was most important to the consumers given that these were the key factors that were important to the consumer. This insight not only clarified the sensory expectations surrounding neem but also offered guidance for developing a prototype that would likely perform well in consumer acceptance testing.

This case illustrates the strategic advantage of conjoint analysis in early-stage product development particularly for IFV-based products, which may be unfamiliar or underutilized. By identifying which attribute combinations resonate most with consumers, developers can focus resources on formulations that balance sensory appeal with health, cultural relevance, and practicality. Additionally, conjoint analysis complements other sensory tools such as descriptive profiling and acceptance testing, making it a crucial component in a comprehensive, consumer-driven product development framework.

Conjoint analysis equips developers with evidence-based insights into consumer priorities and decision-making. When applied thoughtfully alongside other sensory science methods, it ensures that IFV-based innovations are not only nutritionally sound and culturally meaningful but also market-ready and aligned with consumer expectations.

4 Conclusions and recommendations on consumer-led product development

This review has explored how sensory and consumer science tools such as descriptive profiling, surveys and conjoint analysis can be used strategically in the development of food products based on IFVs. The CLPD approach, as illustrated throughout the paper, offers a powerful framework for aligning nutritional innovation with real-world consumer preferences. However, for

CLPD to be successfully applied in practice, certain considerations must be addressed, and the approach must be both well-resourced and thoughtfully executed.

4.1 Challenges to address when using a consumer-led approach

While CLPD provides significant benefits, it also comes with practical challenges. Engaging consumers meaningfully throughout the development process requires careful planning, ethical considerations (particularly when working with vulnerable groups like children), and access to diverse populations. The process can be resource-intensive, requiring time, trained personnel, and coordination between sensory scientists, marketing teams, and product developers (Guiné et al., 2020). Another challenge lies in managing expectations—both from consumers, who may anticipate immediate product availability, and from development teams, who may underestimate the time required to integrate iterative feedback effectively. In contexts involving IFVs, developers may also contend with negative perceptions or limited familiarity, which can affect how consumers engage with and evaluate prototypes.

4.2 Advantages of consumer-led product development

Despite these challenges, the advantages of CLPD are substantial. It increases the likelihood that products will succeed in the marketplace by grounding development in real needs, preferences, and sensory expectations. It also enhances consumer satisfaction and trust by offering products that feel personally relevant and culturally appropriate. In the context of IFVs, CLPD can play a transformative role in repositioning traditional ingredients within modern diets, thereby supporting biodiversity, local economies, and public health (Van Trijp and Steenkamp, 2005).

CLPD also promotes cross-functional collaboration, encouraging scientists, marketers, and product developers to work together from the start. This leads to more cohesive and targeted product strategies and better alignment between product features and consumer value.

4.3 Limitations and factors for success

In contrast to its advantages despite its participatory nature, consumer preferences are not always static or rational. They can be shaped by marketing, trends, or situational factors that may not be stable over time. Therefore, the insights gained from one round of testing may have a limited shelf life or relevance in other markets or cultural contexts (Guiné et al., 2020). Moreover, consumer-led approaches do not always guarantee success if used in isolation. They must be integrated with technical, regulatory, and nutritional considerations, especially when developing products for specific dietary needs or health goals. Relying solely on consumer preferences may also undervalue emerging innovations that consumers are not yet familiar with but could accept once properly introduced (Van Trijp and Steenkamp, 2005). To mitigate some of these challenges, certain attitudes and steps must be adopted when using the CLPD approach.

First, management buy-in and institutional support is crucial to reduce the limitations of the CLPD approach and enhance the chances of success. CLPD requires an investment of time and resources, and without leadership commitment, it is difficult to sustain the process (Jaeger and MacFie, 2010; Falahat et al., 2024). Secondly, developers must use the right tools and methodologies from properly designed surveys and descriptive profiling protocols to validated conjoint analysis platforms. A most abused tool, the consumer acceptance test must be used appropriately considering the target consumer, the context of the test and the scale type used. The use of robust tools ensures that consumer data is reliable and actionable. Time is also an essential factor. CLPD is not a one-off activity but a process that unfolds over stages from initial exploration and concept testing to prototype evaluation and reformulation (Hagan et al., 2018). Teams must be willing to iterate, revisit assumptions, and allow insights to emerge organically rather than forcing outcomes too quickly (Fuller, 2004). Finally, the process must be guided by a clear and actionable objective. Understanding the development context whether nutritional, cultural, or market-driven is vital for interpreting consumer data accurately and making informed development decisions (Fuller, 2004; Falahat et al., 2024).

Consumer-led product development offers a practical, inclusive, and evidence-based approach to food innovation, particularly for underutilized products like Indigenous Fruits and Vegetables. By combining rigorous sensory science with deep consumer engagement, it is possible to develop food products that are not only nutritious and culturally resonant but also desirable, competitive, and impactful. As food systems evolve to meet the health, environmental, and cultural challenges of our time, placing the consumer at the heart of product innovation is not just a strategy, it is a necessity.

Author contributions

MA: Resources, Funding acquisition, Project administration, Writing – original draft, Supervision, Writing – review & editing, Conceptualization, Methodology. AO: Methodology, Formal analysis, Writing – review & editing. JoA: Writing – review & editing, Funding acquisition, Supervision. CA: Methodology, Writing – original draft, Formal analysis, Investigation. EA-P: Investigation, Writing – original draft, Methodology, Formal analysis. BT: Methodology, Writing – original draft, Investigation, Formal analysis. FA: Project administration, Writing – review & editing, Funding acquisition. JaA: Project administration, Funding acquisition, Resources, Writing – review & editing.

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Conflict of interest

AO was employed by Sentinel Foods R&D, PAMP Ghana Ltd.

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Generative AI statement

The author(s) declared that Generative AI was used in the creation of this manuscript. ChatGPT-4o free version was used to improve the grammar and clarity of this paper. The authors declare that they in no way used the AI tool to write full sections of this document. Rather

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