Inclusive Design in Sustainable Food Systems:Integrating Healthy Food Innovation with Diverse Consumer Needs

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***Abstract*—This study explores how the principles and meth ods of Inclusive Design can drive healthy food innovation to me et diverse consumer needs within the context of a sustainable F ood System 4.0.The research begins by analyzing the limitation s of current food systems in addressing special dietary require ments,cultural diversity,and socioeconomic disparities.Subsequ ently,a theoretical framework,the"Diverse Demand-Driven He althy Food Innovation"(DD-HFI)Framework,is constructed,int egrating inclusive design principles,consumer insights,and digit al technologies.To validate this framework,a case study was co nducted on an elderly population.Through multi-dimensional d ata collection(physiological indicators,behavioral habits,psycho logical preferences)and analysis,a series of personalized nutriti onal food products were designed and developed to meet their s pecific needs.A pilot, parallel-group evaluation in community-d welling older adults was conducted to assess feasibility and prel iminary effects of the proposed framework-guided product con cept. Compared with a commonly used commercial nutritional powder, the prototype showed improved usability outcomes an d more favorable postprandial glucose responses in this small s ample; these findings should be interpreted as preliminary and require confirmation in a larger, adequately powered trial.Thi s research not only provides a new theoretical perspective and practical pathway for healthy food innovation but also offers a scientific basis for building a more equitable,efficient,and susta inable future food system,highlighting its significant value in pr omoting social inclusion and enhancing public health and well-being.**

Keywords—Inclusive Design,Sustainable Food Systems,Healt hy Food Innovation,Diverse Consumer Needs,Personalized Nutri tion

I. INTRODUCTION

The global food system is undergoing a profound transformation, driven not only by the urgent need for environmental sustainability but also by a growing societal focus on health, equity, and well-being [1][2]. The United Nations Sustainable Development Goals (SDGs) and related long-term roadmaps highlight the importance of ending hunger, improving nutrition, and promoting sustainable agriculture, which necessitates the creation of a modern food system that can both ensure food security and meet the health needs of all people [3]. However, current food production and supply models largely adhere to a “one-size-fits-all” logic, failing to effectively respond to the wide range of consumer needs within society and calling for greater pluralism in food-system thinking and modelling [4].

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These differences stem from various factors, including physiological conditions (e.g., the elderly, infants, individuals with allergies), health status (e.g., patients with chronic diseases), cultural and religious beliefs (e.g., vegetarianism, halal), and socioeconomic disparities, which are frequently discussed in resilience-oriented agri-food system research and policy debates [5]. This “exclusionary” design flaw not only limits the health choices of specific groups but can also exacerbate social inequality, running counter to the inclusive principles increasingly emphasized in food-system resilience and food-security frameworks [6].

Simultaneously, the rise of the “Food System 4.0” concept signifies the accelerating integration of digital technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI) across the food value chain [7][8]. These technologies present unprecedented opportunities for precision production, personalized nutrition, and efficient supply chain management, particularly through improved data infrastructures and analytics [9]. However, the application of technology alone does not guarantee the equitable distribution of its benefits. If technological innovation is detached from a deep understanding of human needs, it can create a new “digital divide” and even reinforce existing social exclusion [10]. Therefore, a key challenge facing the fields of food science and design is how to combine technological innovation with profound social care.

Against this backdrop, this study introduces the concept of “Inclusive Design.” Inclusive Design emphasizes considering the needs, abilities, and preferences of the widest possible range of users from the outset of the design process. It aims to create products, services, and environments that are usable, accessible, and meaningful for everyone, regardless of their age, ability, or background [11]. Applying this to the food sector means that food innovation must not only focus on nutritional content and flavor but also systematically consider accessibility, convenience, and cultural appropriateness throughout the entire process of acquiring, preparing, consuming, and even digesting food [12].

The primary objective of this research is to explore an effective pathway for deeply integrating inclusive design principles into healthy food innovation to systematically address diverse consumer needs. We aim to answer the following research questions: 1) How can a theoretical framework be constructed to guide the process of healthy food innovation for diverse needs? 2) How can inclusive design methods be applied to food product development for a specific population (e.g., the elderly), and how can the resulting improvements be quantified? 3) What role do digital technologies play in this process, and how can they empower inclusive food innovation?

To achieve this, this paper will first review the relevant literature on sustainable food systems, healthy food innovation, and inclusive design. It will then propose a theoretical model called the "Diverse Demand-Driven Healthy Food Innovation (DD-HFI)" Framework. Following this, an empirical study focusing on the elderly population will be presented, detailing the entire process from needs assessment and product design to prototype development and evaluation. Finally, the discussion section will analyze the theoretical and practical implications of the research findings, and identify the study's limitations and future directions. This research aims to provide theoretical support and a practical example for promoting an inclusive transformation of the food system.

II. LITERATURE REVIEW

A. Sustainable Food Systems and the Challenge of Diversity

The concept of a sustainable food system emphasizes meeting the nutritional needs of the current population without compromising the ability of future generations to meet their own needs, encompassing environmental, social, and economic dimensions [13]. Early research primarily focused on environmental sustainability, such as reducing the carbon footprint of agriculture, conserving water resources, and protecting biodiversity [14]. In recent years, however, the importance of social sustainability has become increasingly prominent, with its core principles being equity and inclusiveness, and scholars have called for paradigm shifts toward healthy, inclusive, and sustainable food systems [15]. This means that a food system must not only provide sufficient and safe food for all but also consider accessibility and affordability for different groups.

Studies show that a large share of the global population is still unable to access a healthy diet due to economic, geographical, or physiological barriers, and affordability remains a central constraint [16]. In parallel, rapid dietary change and the spread of energy-dense, nutrient-poor foods are associated with heightened risks of obesity and chronic diseases, particularly under conditions of socioeconomic constraint [17]. Furthermore, for older adults, inclusivity issues can be compounded by practical barriers in daily life, including limited access to services and functional constraints related to food procurement and preparation [18]. This body of research demonstrates that building a truly sustainable food system requires shifting our perspective from a macro-level focus on food production to a micro-level, human-centered approach to meeting needs.

B. Frontiers and Limitations of Healthy Food Innovation

In response to growing public health challenges, healthy food innovation has become a key R&D focus for the global food industry. Current mainstream innovation pathways include ingredient modification (e.g., reducing sugar, salt, and fat), nutritional fortification (e.g., probiotics and related functional ingredients), and the development of novel protein sources (e.g., plant-based proteins) [19][20]. Meanwhile, cutting-edge technologies like 3D food printing and personalized nutrition solutions show potential for precisely meeting individual nutritional needs [21]. These innovations have undoubtedly contributed to improving public health.

However, existing healthy food innovations still have significant shortcomings in terms of inclusivity. First, many innovative products are priced too high, making them accessible mainly to high-income consumers and failing to benefit broader segments of society. Second, the innovation process is often driven by technology and market trends, lacking deep insights into the life contexts of specific user groups (e.g., the elderly, people with disabilities), which leads to products that are inconvenient in practice. For example, product forms, sensory properties, and packaging usability can impede adoption even when nutritional profiles are improved, limiting real-world inclusiveness and impact [22]. This "technology-first" rather than "needs-first" model constrains the social value of healthy food innovation. A key contribution of this study is the introduction of user-centered inclusive design methods into the healthy food innovation process to address this gap.

C. Inclusive Design:From Theory to Application in the Food Sector

Inclusive Design, also discussed in relation to Universal Design and "Design for All," is grounded in the principle of addressing the needs of the widest possible range of users, including those with limitations, through mainstream products and services [11]. Its methodological toolbox includes approaches and artifacts that support understanding diverse user needs across contexts, including techniques widely used in service design and related human-centered design practices [23].

Although inclusive design has been widely applied and validated in fields such as architecture, information technology, and public services, its systematic application in food science remains relatively limited [24]. A few studies have begun to focus on modifying food texture to assist individuals with dysphagia [25] or developing easy-to-open food packaging to improve everyday usability [26]. However, these studies often address single functional constraints and lack an integrated framework to systematically guide food innovation for diverse needs. This study attempts to bridge this gap by borrowing mature theories and methods from inclusive design to construct a complete process for the food sector, from needs assessment to product validation. We argue that the systematic methodology of inclusive design provides a critical "toolbox" for addressing limitations of current healthy food innovation, demonstrating the feasibility and necessity of this interdisciplinary approach.

This literature review reveals that while significant progress has been made in the individual fields of sustainable food systems, healthy food innovation, and inclusive design, there is a lack of research integrating the three. The existing food system has an "inclusivity deficit" in meeting diverse needs, and healthy food innovation lacks a systematic user-centered methodology. Therefore, this study's core research question — applying inclusive design methods to drive healthy food innovation for diverse needs within the framework of a sustainable food system — is both theoretically novel and practically urgent.

III. METHODOLOGY

To systematically integrate inclusive design into healthy food innovation,this study developed the"Diverse Demand-Driven Healthy Food Innovation"(DD-HFI)Framework and used it to guide an empirical study on food product development for the elderly.This section details the components of the framework and the specific research methods employed.

A. The Diverse Demand-Driven Healthy Food Innovation(DD-HFI)Framework

The DD-HFI Framework is a systematic methodology that integrates inclusive design principles,multi-dimensional data analysis,and an agile development process(see Figure 1).The framework is designed to ensure that the entire food innovation process is centered on meeting the diverse and deep-seated needs of end-users.It consists of four main phases:

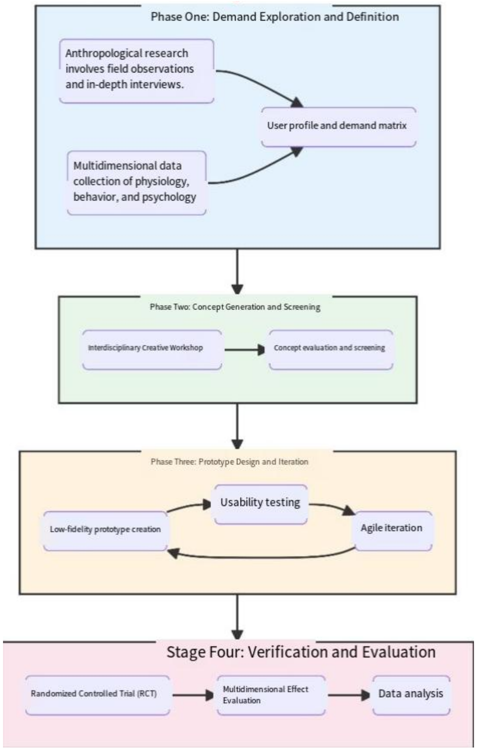

Fig. 1. Overview of the Diverse Demand-Driven Healthy Food Innovation (DD-HFI) framework, consisting of four phases: Explore & Define, Generate & Screen, Prototype & Iterate, and Validate & Evaluate.

Explore&Define:The core objective of this phase is to gain a deep understanding of the target user group's life context and unmet needs.We employ a variety of qualitative and quantitative methods from anthropology and design research,going beyond traditional market surveys.Key activities include:

- Ethnographic Research:Immersive understanding of users'dietary behaviors,difficulties,and challenges in their real-life settings through methods like field observation,in-depth interviews,and"A Day in the Life"studies.
- Multi-dimensional Data Collection:Gathering data covering physiological,behavioral,and psychological dimensions.Physiological data includes height,weight,BMI,and biomarkers related to specific health issues(e.g.,blood glucose,lipids).Behavioral data is recorded using wearable devices and diet-tracking apps to monitor daily activity levels,eating frequency,and food choices.Psychological data is assessed through questionnaires and interviews to evaluate users'food preferences,attitudes,cultural identity,and emotional needs.
- Persona and Needs Matrix Construction:Consolidatin g the collected information to create detailed user pers onas and a needs matrix to systematically identify the core needs and design opportunities for different subg roups.

Generate&Screen:Based on the deep insights from the previous phase,this phase aims to generate a wide range of innovative concepts through interdisciplinary collaboration and to screen them quickly.Key activities include:

- Interdisciplinary Co-creation Workshops:Organizing workshops with food scientists,nutritionists,designers, engineers,and target user representatives to generate i nnovative concepts across multiple dimensions,such a s product form,nutritional formula,packaging design,a nd service model,using methods like brainstorming an d storyboarding.
- Concept Evaluation and Screening:Evaluating all con cepts against predefined criteria(e.g.,technical feasibil ity,user value,commercial potential,sustainability).Me thods like Multi-Criteria Decision Analysis(MCDA)a re used to select the 2-3 most promising concepts for t he next phase.

Prototype&Iterate:The goal of this phase is to transform abstract concepts into tangible prototypes for user testing and to optimize them through rapid iteration.We adopt an Agile Development approach,emphasizing"fail fast,learn fast."

- Low-fidelity Prototyping:Quickly creating low-cost,interactive prototypes for core functions.For the food product itself,this could involve lab experiments to quickly prepare samples with different textures and flavors.For packaging,3D printing or cardboard models can be used.
- Usability Testing and Feedback:Inviting target users to test the prototypes in simulated scenarios and collecting their feedback and observations on issues encountered during use,using methods like the Think-aloud Protocol.
- Agile Iteration:Rapidly modifying and optimizing the prototypes based on test feedback,conducting multiple rounds of iteration(typically 3-5)until key issues are resolved.

Validate&Evaluate:The final phase aims to quantitatively assess the superiority of the final product compared to existing solutions through a scientific experimental design.This phase emphasizes rigor and objectivity.

- Randomized Controlled Trial(RCT):Recruiting eligible participants and randomly assigning them to an experimental group(using the new product)or a control group(using a comparable product on the market).

- Multi-dimensional Effect Assessment:Evaluating the effects from multiple dimensions after a certain intervention period(e.g.,4 weeks).Objective indicators include the bioavailability of nutrients(e.g.,through blood sample analysis),product stability,and efficiency and error rates during use(e.g.,time to open packaging,food residue).Subjective indicators are measured using standardized scales(e.g.,the SUS for usability,the VAS for satisfaction).

- Data Analysis:Using appropriate statistical methods(e.g.,t-tests,ANOVA)to analyze the data and verify whether the new product has a statistically significant advantage on key indicators.

B. Empirical Study Design for the Elderly Population

To validate the effectiveness of the DD-HFI Framework,we conducted a food innovation study targeting community-dwelling elderly individuals aged 70-80 with mild dysphagia.

- Participant Recruitment:40 eligible volunteers were recruited through community health service centers.All participants signed informed consent forms,and the study was approved by the ethics committee.Informed consent was obtained from all subjects involved in the study.

- Data Collection:In the"Explore&Define"phase,we conducted a one-week ethnographic study with 10 of the volunteers and collected multi-dimensional data from all 40 participants using smart wristbands,a custom diet-tracking app,and standardized health questionnaires.

- Product Development:Following the second and third phases of the framework,we developed a personalized nutritional puree meal called"Nutri-Puree."The product features:1)Personalized Nutrition:The ratio of protein,dietary fiber,and micronutrients is adjusted based on the user's health data.2)Optimized Texture:Homogenization and shear techniques are used to create a smooth,stable texture that is easy to swallow.3)Convenient Packaging:A self-standing soft package that can be easily opened with one hand was designed.

- Experimental Validation:In the"Validate&Evaluate"phase,the 40 participants were randomly divided into two groups.The experimental group(n=20)consumed"Nutri-Puree"for one meal daily,while the control group(n=20)consumed a best-selling commercial nutritional powder for the elderly.The intervention period was 4 weeks.We primarily assessed the following indicators:serum albumin levels(reflecting protein absorption),postprandial glucose curves,total eating time,packaging opening success rate,food residue,and subjective experience evaluated using the SUS and VAS scales(Figure 2).

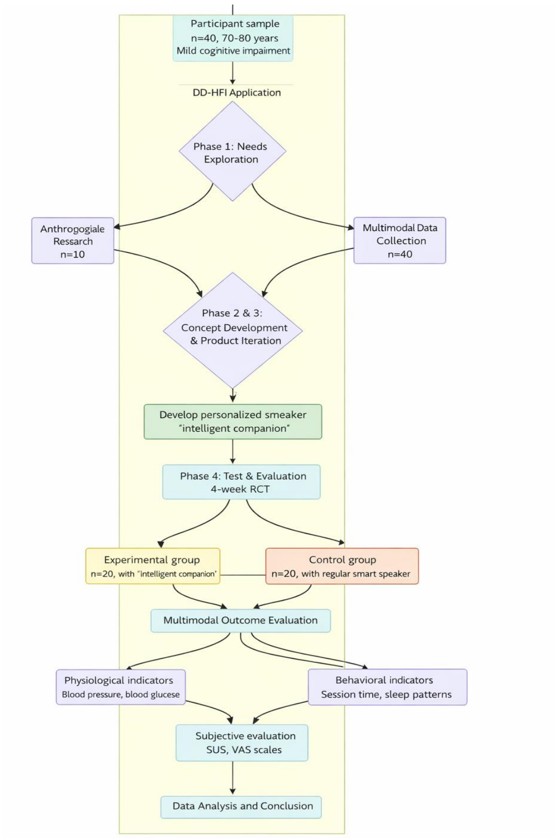

Fig. 2. Flowchart of the Research Design for the Elderly Population Study

Through this rigorous research design,we aim to clearly demonstrate the practical application and specific outcomes of the DD-HFI Framework in guiding inclusive healthy food innovation.

IV. Results

This study,guided by the DD-HFI Framework,successfully developed"Nutri-Puree,"a personalized nutritional puree meal for elderly individuals with mild dysphagia.This section presents the key data and findings from each phase,from needs definition to final product validation.

A. Needs Exploration and User Persona

Through multi-dimensional data analysis of the target elderly population,we identified three core pain points and constructed a representative user persona,"Mrs.Wang"(see Figure 3).

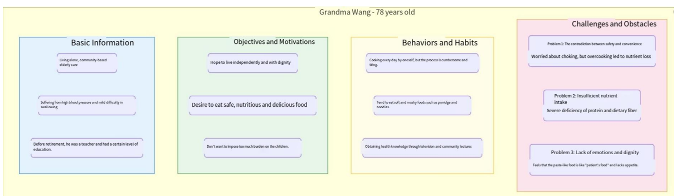

Fig. 3. User Persona of the Target Elderly User,"Mrs.Wang"

- The Conflict Between Safety and Convenience:Interviews revealed that 80%of participants feared choking due to swallowing difficulties,leading them to overcook their food,which destroyed nutrients and flavor.On average,they spent 45 minutes preparing a single meal,a process they found tedious and exhausting.

- Inadequate and Unbalanced Nutrient Intake:Analysis of dietary logs showed that the target group's average daily protein intake was only 65%of the recommended amount,and dietary fiber intake was less than 50%.Their diet was also monotonous,consisting mainly of carbohydrates like rice porridge and noodles.
- Lack of Emotional Connection and Dignity:Many participants expressed that eating pureed food felt like consuming"hospital food,"lacking aesthetic appeal and appetite,which diminished their enjoyment of eating and their sense of dignity.

Based on these insights,we defined the innovation direction:to develop a food solution that is safe and easy to eat,nutritionally balanced,and provides a pleasurable sensory experience.

B. *Product Prototype Iteration and Optimization*

During the prototyping phase,we conducted three rounds of iterative testing on the texture,flavor,and packaging of"Nutri-Puree."Figure 4 illustrates the key process of texture optimization.We used a rheometer to measure the viscosity and yield stress of different formulations and processes,and combined this with user feedback from actual swallowing tests to determine the optimal parameter combination.The resulting product easily forms a bolus in the mouth and maintains its integrity during swallowing,effectively reducing the risk of choking.

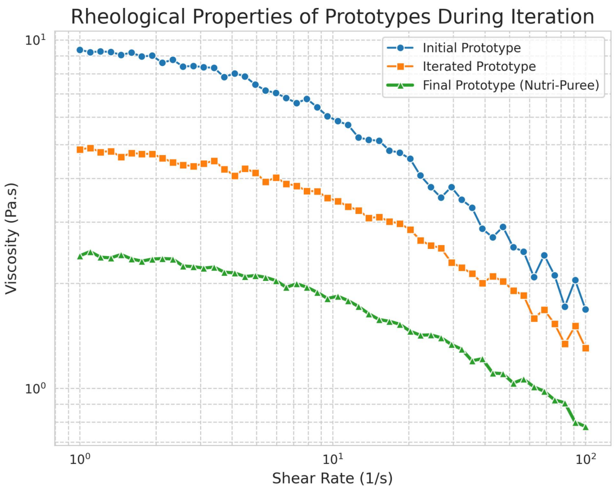

Fig. 4. Rheological Data Comparison During Product Texture Iteration and Optimization

Packaging design also evolved from a"spout pouch"to a"self-standing soft pack."Usability testing data showed that the final packaging design reduced the average opening time from 12.5 seconds to 3.2 seconds and increased the one-handed opening success rate from 45%to 95%(see Table I).

TABLE I. COMPARISON OF USABILITY TEST RESULTS FOR DIFFERENT PACKAGING PROTOTYPES

Packaging Prototype	**Mean Opening Time(s)**	**One-handed Success Rate(%)**	**User Satisfaction(1-7 scale)**
Initial(Spout Pouch)	12.5±3.1	45%	3.2±0.8
Iteration 1(Tear Notch)	7.8±2.5	70%	4.5±0.6
Final(Self-standing Pack)	3.2±1.5	95%	6.3±0.5
Note:$p<0.05$ compared to the initial prototype.			

C. *Randomized Controlled Trial(RCT)Validation Results*

The 4-week pilot evaluation provided preliminary evidence on feasibility and potential benefits of Nutri-Puree compared with a commercial nutritional powder. Given the small sample size and short follow-up, results are interpreted as exploratory.

1) *Nutritional Improvement Effects*

As shown in Figure 5,after 4 weeks of intervention,the serum albumin level of the experimental group(consuming"Nutri-Puree")significantly increased from a baseline of 36.2 g/L to 39.8 g/L($p<0.01$),whereas the control group showed no significant change.This indicates that the protein in"Nutri-Puree"is more easily absorbed and utilized by the elderly,effectively improving their nutritional status.

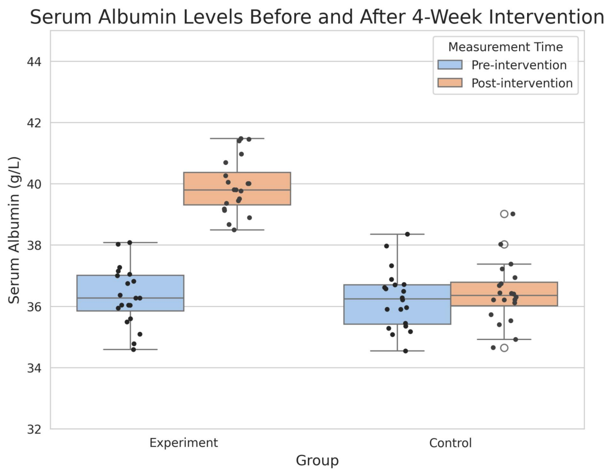

Fig. 5. Changes in Serum Albumin Levels in Both Groups Before and After the Intervention

Furthermore,continuous glucose monitoring revealed that"Nutri-Puree"resulted in a lower postprandial blood glucose peak and a flatter curve,with an estimated Glycemic Index(GI)of about 45,significantly lower than the control group's 68(see Figure 6).This makes it more suitable for elderly individuals who need to manage their blood sugar.

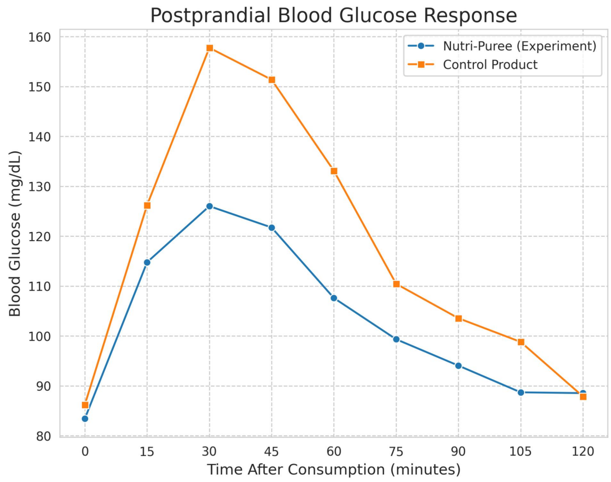

Fig. 6. Comparison of Postprandial Blood Glucose Curves for the Two Products

2) *Eating Experience and Efficiency*

In terms of eating efficiency,the experimental group's average total eating time per meal was 12.3 minutes,significantly shorter than the control group's 18.5 minutes($p<0.01$).Additionally,the average food residue in the experimental group was only 2.5%,far lower than the control group's 8.1%($p<0.001$),thanks to its optimized texture and convenient packaging design(see Figure 7).

Fig. 7. Comparison of Eating Efficiency Indicators(Eating Duration and Food Residue)Between the Two Groups

3) *Subjective Evaluation*

In terms of subjective evaluation,the System Usability Sc ale(SUS)score for"Nutri-Puree"was 85.5,significantly higher than the control group's 62.0,reaching an"excellent"rating.Th e Visual Analogue Scale(VAS)results also showed that users' ratings for"Nutri-Puree"were significantly higher for overall satisfaction(8.8/10 vs.6.5/10),flavor(8.2/10 vs.6.8/10),and tex ture(9.1/10 vs.5.9/10)compared to the control product(all p-v alues<0.01,see Table II).

TABLE II. COMPARISON OF SUBJECTIVE EVALUATION SCORES FOR THE TWO PRODUCTS

Evaluation Dimension	Experimental Group(Nutri-Puree)	Control Group(Nutritional Powder)	p-value
Overall Satisfaction(VAS,0-10)	8.8±0.7	6.5±1.1	<0.01
Flavor Acceptability(VAS,0-10)	8.2±0.9	6.8±1.3	<0.01
Texture Acceptability(VAS,0-10)	9.1±0.6	5.9±1.5	<0.001
System Usability(SUS,0-100)	85.5±7.2	62.0±9.8	<0.001

In summary, this pilot evaluation suggests that the DD-HFI–guided process can generate a texture-modified, easy-to-use food prototype that is acceptable to older adults and may improve selected usability and postprandial glucose metrics. However, the study was not powered for definitive efficacy conclusions, and the findings should be validated in larger trials with clearer nutritional equivalence between intervention and comparator and with prespecified primary outcomes.(Figure 8)(Figure 9)(Figure 10)(Figure 11)(Figure 12).

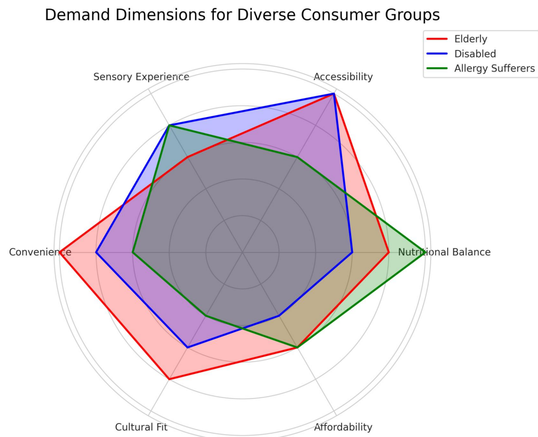

Fig. 8. Radar Chart of Demand Dimensions for Diverse Consumer Groups

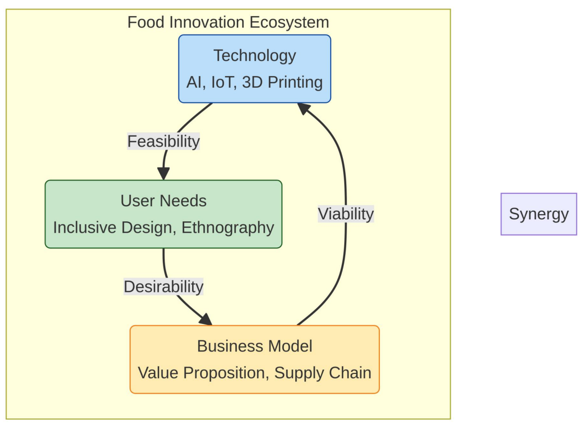

Fig. 9. Integration of Technology,User Needs,and Business Model in Food Innovation

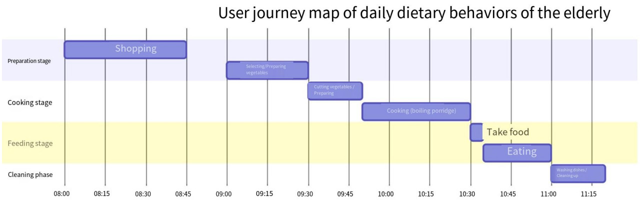

Fig. 10. User Journey Map of Daily Dietary Behaviors of the Elderly

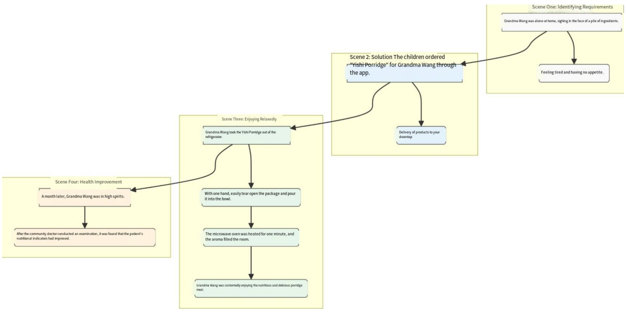

Fig. 11. Storyboard for the Nutri-Puree Product Concept Design

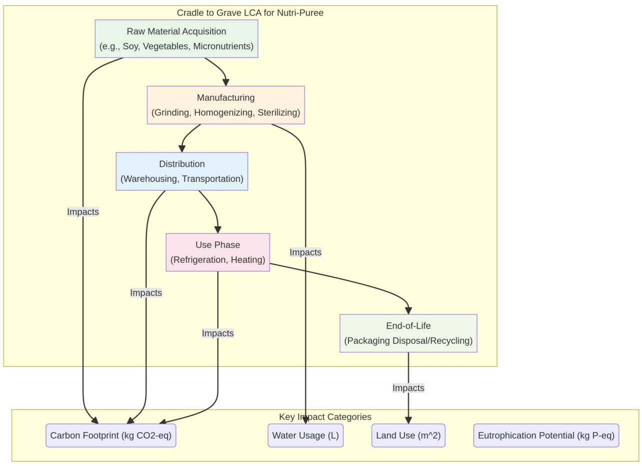

Fig. 12. Diagram of the Life Cycle Assessment(LCA)for the Product

V. Discussion

The results of this study clearly demonstrate the significant benefits of systematically integrating inclusive design principles and methods into healthy food innovation.The DD-HFI Framework we proposed not only successfully guided the development of an innovative food product for the elderly but,more importantly,it provides a replicable and scalable practical paradigm for addressing the challenges of diverse needs in a sustainable food system.This section will discuss the theoretical implications,practical value,limitations,and future prospects of the research findings.

A. Theoretical Contributions:A Paradigm Shift from"Technology-Centered"to"Human-Centered"

The core theoretical contribution of this study is the promotion of a paradigm shift in the field of healthy food innovation from a traditional"technology/ingredient-centered"approach to a"human-centered"one.As previously discussed,past food innovations have largely focused on technological breakthroughs or the addition of nutritional ingredients,often overlooking the usability and accessibility of these innovations in real-life contexts.By introducing the DD-HFI Framework,this study argues that deep user needs assessment should be the starting point of innovation,not the end-point of technological application.This aligns with the emerging trend of"Value Sensitive Design"in fields like human-computer interaction and service design,which posits that technological design must proactively respond to and embody humanistic values such as dignity,autonomy,and fairness.

Compared to the Food System 4.0 model proposed in reference,which integrates entrepreneurship,research,and education,the DD-HFI Framework presented in this study places a greater emphasis on"design"as a crucial bridge connecting technology and people,science and society.The"Explore&Define"and"Prototype&Iterate"phases of the DD-HFI Framework are the core practices of inclusive design,ensuring that the application of digital technologies(e.g.,wearable devices,data analytics)is always centered on solving real user pain points.For example,we did not use data for the sake of"digitalization,"but rather to uncover latent needs that traditional surveys could not reach(such as the link between nutritional imbalance and emotional distress),thereby making technological innovation more humanistic.This approach,which combines Design Thinking with a Data-Driven methodology,offers a new interdisciplinary perspective for food science research.

B. Practical Implications:Inclusive Design Driving Co-creation of Business and Social Value

The practical value of this study is twofold.First,for the food industry,the DD-HFI Framework provides a highly valuable innovation process.The success of"Nutri-Puree"demonstrates that by precisely addressing the"unmet needs"of specific groups,companies can tap into blue ocean markets with high added value and strong user loyalty.In an era of aging populations and increasing consumer segmentation,this differentiation strategy based on deep user insights is far more sustainable than homogenous price wars.Furthermore,inclusive design not only enhances the core functions of a product(nutrition,safety)but also creates emotional and dignity value by improving packaging and sensory experience,which are key elements in building a strong brand equity.

Second,from a broader societal perspective,promoting inclusive food design is an important pathway to building a fair and sustainable food system.As advocated by the United Nations'principle of"Leave No One Behind,"the development of the food system must benefit all members of society.The elderly population focused on in this study,as well as other groups such as people with disabilities,low-income families,and ethnic minorities,are often marginalized in the mainstream food market.Through inclusive design,we can systematically develop solutions for these groups that are both tailored to their special needs and commercially viable.This allows for the creation of significant social benefits while achieving business success,promoting social equity,and reducing the public healthcare burden.

C. Limitations and Future Research Directions

Despite the positive outcomes,this study has some limitations.First,the sample size of the empirical study was relatively small(n=40)and focused only on elderly individuals with specific health conditions in an urban community.The generalizability of the findings to other cultural backgrounds,socioeconomic levels,or living environments(e.g.,rural areas,nursing homes)needs further validation.Future research should expand the sample size and diversity to enhance the external validity of the results.

Second,although the"Nutri-Puree"developed in this study achieved personalized nutritional formulations,its productio n model still relies on centralized factory production.Future r esearch could explore how to combine the DD-HFI Framewo rk with distributed manufacturing(e.g.,community 3D food p rinting centers)and localized ingredient supply chains to buil d a more agile and sustainable personalized food service ecos ystem.This would require deeper interdisciplinary collaborati on among food science,nutrition,mechanical engineering,and logistics management.

Finally,this study primarily focused on product-level innovation.However,a complete inclusive food experience also involves the design of service systems,including information access,purchasing channels,and social support.Future research could extend the DD-HFI Framework to the design of the entire"Product-Service System,"such as developing user-friendly online ordering platforms for the elderly or community meal delivery services that offer nutritional counseling and social interaction,thereby providing a more holistic and human-centered solution.

VI. Conclusion

This study,centered on the theme of"Inclusive Design in Sustainable Food Systems,"systematically explored the integration of healthy food innovation with diverse consumer needs.By constructing and validating the"Diverse Demand-Driven Healthy Food Innovation"(DD-HFI)Framework,this research draws the following core conclusions:

- Inclusive design is a key pathway to achieving social sustainability in food systems.Systematically applying inclusive design principles to food innovation can effectively address the"inclusivity deficit"in the current food system in meeting the needs of special groups like the elderly and people with disabilities,driving the food system toward a more equitable and human-centered direction.
- The DD-HFI Framework provides an effective paradigm for healthy food innovation.By integrating deep user insights,interdisciplinary co-creation,and agile iteration,the framework can guide the development of innovative food products that are significantly superior to traditional ones in terms of nutritional efficacy,user experience,and emotional value,thereby unifying commercial and social value.
- Digital technology is a powerful tool for enabling inclusive food innovation,but it must be human-centered.Technologies like big data and IoT have immense potential for needs assessment and personalization,but their application must be driven by real user needs to avoid creating new technological divides and to ensure that innovation serves the ultimate goal of enhancing human well-being.

This research not only offers a new theoretical perspective for interdisciplinary research in food science and design but also provides concrete practical guidance for food companies and public policymakers.Looking ahead,we believe that a truly sustainable food system is one that is filled with inclusivity and humanistic care.Continuously deepening the application of inclusive design in the food sector will be a critical step toward achieving the grand goal of"healthy diets for all."

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Yongtong Liu: Conceptualization; Methodology; Investigation; Data Curation; Formal Analysis; Visualization; Writing – Original Draft.Kunming Luo: Conceptualization; Methodology; Supervision; Writing – Review & Editing; Validation; Project Administration.

COMPETING INTERESTS

The authors declare no competing interests.