3D SUSTAINABLE PRINTED FOOD

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RESEARCH ARTICLE

Abstract
Food waste is a globally recognized issue and one of the most urgent challenges shaping future agri-food systems. As one of the most pressing global problems, it mobilizes increasing numbers of stakeholders who acknowledge the need to act quickly and decisively(Kuisma & Kahiluoto, 2017). However, food waste is not the only issue. Children continue to avoid vegetables and proteins; older adults face texture-related difficulties in eating; and athletes seek high-protein, functional snacks with controlled macros. The need for personalized, inclusive, and nutritious food solutions is greater than ever. FARM FAB is an innovative food-tech solution that merges 3D printing technology with the principles of sustainability, nutrition personalization, and food valorization(Liu et al., 2017). This project aims to transform local, imperfect, or underused ingredients into nutritious food pastes referred to as "edible inks" to create customized meals using a smart 3D printer connected to a user-friendly application. Designed for diverse target groups such as children, the elderly, athletes, and even astronauts, FARM FAB addresses food waste, dietary needs, and sensory appeal through texture and visual design. The system integrates sustainable sourcing, personalized nutrition, and advanced food engineering, with future potential in schools, healthcare, gastronomy, and space missions. By promoting the circular economy and healthy eating habits, FARM FAB aspires to revolutionize how we design, prepare, and consume food.

Keywords: 3D Food Printing, Food waste, personalized nutrition, sustainable food innovation, Edible inks, Local ingredients.
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INTRODUCTION

Food waste is a globally recognized issue and one of the most urgent challenges shaping future agri-food systems one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year(Cederberg & Sonesson, 2011). As one of the most pressing global problems, food waste not only represents a loss of valuable resources but also contributes significantly to environmental degradation and inequality. It is a challenge that increasingly mobilizes researchers, innovators, and public institutions.

At the same time, the food system faces additional challenges: many children refuse to eat vegetables or proteins; elderly people often require soft-textured meals for easier chewing and digestion; and athletes demand nutrient-dense, protein-rich snacks with tailored macronutrients. All of these issues highlight a broader need for personalized, nutritious, and culturally relevant food solutions (Liu et al., 2017).

FARM FAB is an innovative food-tech project that combines 3D food printing technology with local ingredient valorization, nutrition personalization, and sustainable development. In a context of increasing food waste, growing demand for tailored nutrition, and rising interest in circular economy practices, this project proposes a complete system (machine + mobile app + printable food recipes) designed to adapt meals to various dietary profiles using locally sourced or "imperfect" agricultural ingredients.

The primary aim is to address multiple issues simultaneously: food waste, inadequate nutritional solutions for specific populations, underuse of regional products, and the modernization of traditional food through an accessible, intelligent, and inclusive platform.

MATERIAL AND METHOD

FARM FAB is a food-tech startup project designed to meet the nutritional needs of diverse populations while tackling food waste and promoting regional products. Our objective is to build a comprehensive system composed of a user-friendly mobile application, a customizable 3D food printer, and a bank of

printable, nutritious recipes based on local and revalorized ingredients.

1.System components

• The 3D Food Printer: Equipped with multi-cartridge input (up to 4 edible inks), capable of extruding texturized purées or pastes. Optional cooking unit (microwave or infrared).

• Farm Fab App: User selects profile (senior, child, athlete, chef, astronaut), sets nutritional goals (macros), and chooses shapes (cultural symbols, fun forms). The app sends instructions to the printer.

• Printable Recipes: Purées or pastes made from local, ugly, or surplus produce enriched with proteins, fibers, and micronutrients. Example recipes include: almond-date energy bites, beet- carrot crackers, cultural fruit desserts (e.g., shaped like the Kairouan gate), spirulina-chickpea protein balls

2. Development Methodology

• Co-design with food scientists, engineers and designers.

• Formulation of edible inks using food-safe thickeners (agar, xanthan gum).

• Technical testing on printer prototype.

• Pilot demonstrations in agrifood events.

• Branding development (logo, slogan, color scheme).

3. Communication and outreach

• Visual identity created (logo, slogan, color palette).

• Presentations made in startup and academic events.

RESULTS AND DISCUSSIONS

As the FARM FAB project is still in development, the results can be divided into short-term outcomes and long-term expectations.

• Short-Term Outcomes. A functional prototype of a 3D food printer capable of extruding purées. Initial testing with basic edible inks (vegetable and fruit-based). Positivequalitative feedback during early presentations and academic reviews. Interest expressed by professionals in health and culinary sectors.

• Long-Term Expectations: Expanded range of stable, nutritionally targeted food inks. Large-scaleusability studies with target populations (children, seniors, athletes). Integration of cooking features into the printer. Partnerships with local food producers and institutions (schools, clinics).

SWOT Analysis and Michel Porter's Five Forces Model

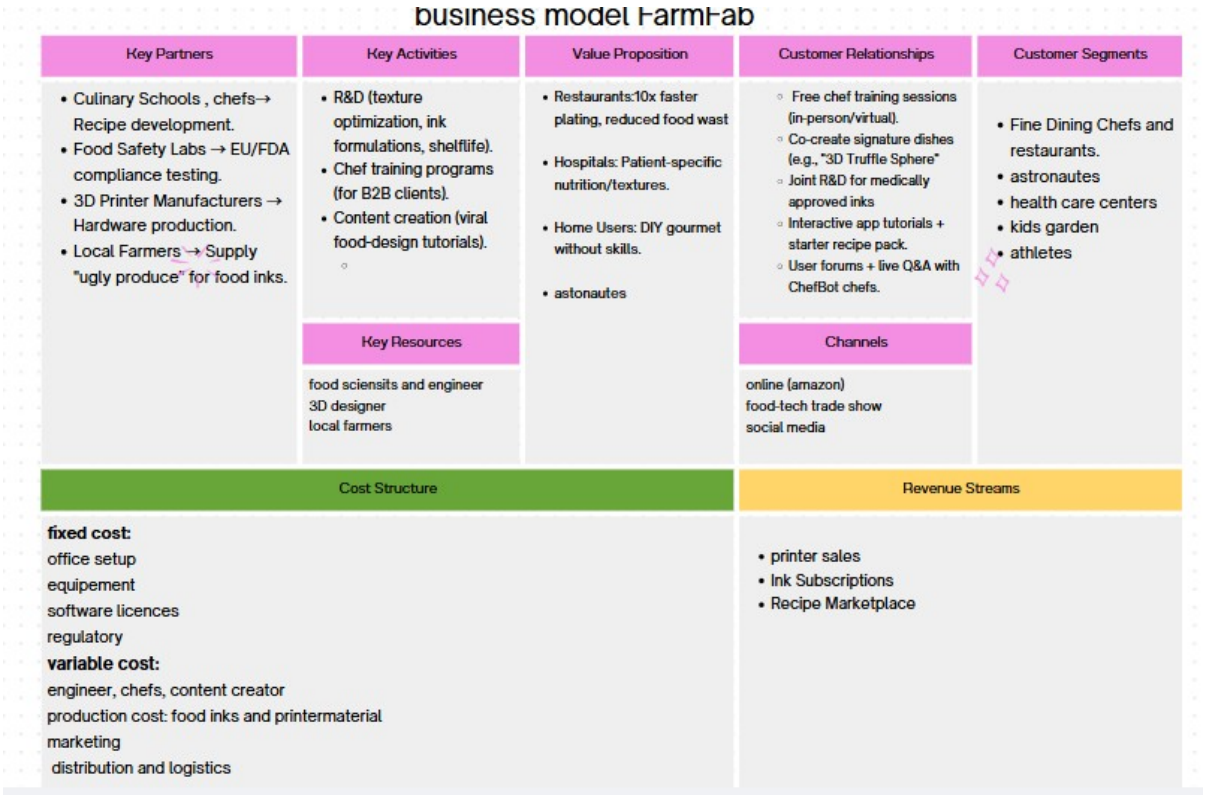
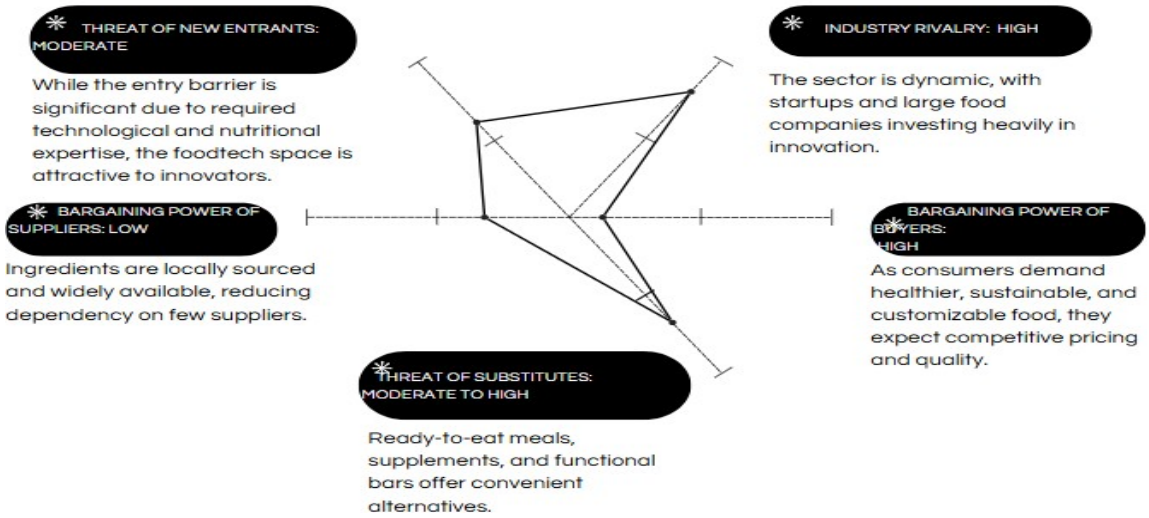


Table 1

PORTER'S FIVE FORCES "FARMFAB"



The SWOT analyses and Porter's Five Forces (appendix) confirm that FARM FAB is positioned within a high-potential but competitive environment. To succeed, the project must maintain a strong value proposition and continue adapting to evolving consumer preferences and regulatory frameworks.

Challenges remain, including:

- Ensuring microbial safety and shelf life of food inks.
- Enhancing social acceptance of 3D-printed meals.
- Addressing cleaning complexity and regulatory compliance.

FARM FAB's approach demonstrates a strong potential to:

- Reduce food waste
- Support local agriculture
- Personalize and modernize nutrition
- Make sustainable innovation accessible across different social groups.

SWOT analysis

Strengths (S)	**Weakness (W)**
-Integration of health, culture, andsustainability. -High adaptability for multiple userprofiles. -Revalorization of local and underusedingredients. -Strong alignment with emerging foodtrends	-Technical immaturity (prototype phase). -Limited public familiarity with 3D-printed food. -High initial cost for early adopters.
Opportunities (O)	**Threats (T)**
-Personalized nutrition market growth. -Collaboration with health institutions, schools, and space programs. -Expansion to developing regions with food waste challenges.	-Regulatory barriers (food safety, labelling). -Fast-paced competition in FoodTec innovation. -Consumer resistance to non-traditional formats.

CONCLUSIONS

FARM FAB represents a new frontier in sustainable and personalized nutrition by harnessing the potential of 3D food printing technology. Its multidimensional value lies not only in reducing food waste and supporting local economies but also in enhancing health through tailored meals and promoting cultural heritage through design. While the project remains under development, early results confirm the technical feasibility and growing public interest.

The strategic analyses (SWOT and Porter's Five Forces) underline both the promising market opportunities and the key challenges to anticipate. Success will depend on continuous innovation, robust food safety measures, and active efforts to build consumer trust.

In the long term, FARM FAB has the potential to become a transformative platform that empowers individuals and institutions from schools and care centers to space agencies to rethink how we source, prepare, and

experience food. By blending functionality, sustainability, and creativity, the project opens the door to a more inclusive, health-conscious, and waste-free food future.

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