

Sustainable Innovation Driven by Women's Agri-Food Cooperatives: Eco-Friendly Products Development from Local Resources in Moroccan Central Rif

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Abstract— Local economies rely heavily on agri-food cooperatives as key drivers of employment, value creation, and conservation of local food heritage. In this context, innovation plays a crucial role in enhancing *terroir* products visibility, boosting market access, and fostering sustainable development. This study aims to support agri-food cooperatives innovation in the Central Rif through a combined survey-based and experimental approach both in the research laboratory and in the cooperative unit through a collaborative workshop. An initial survey was conducted to identify constraints and expectations of local cooperatives regarding sustainable valorization and product diversification. The data were collected from a representative sample of 50 agri-food cooperatives operating in the Central Rif, selected through a stratified systematic sampling method to ensure diversity in terms of sector, size, geographical location, and level of market integration. Based on the identified needs, four eco-friendly prototypes were developed using locally sourced ingredients and green, simple, and easily replicable processing methods. Findings show that more than 50% of the surveyed cooperatives are completely disconnected from the application of sustainable practices, underestimate the value of by-products, and lack knowledge on food waste management along the value chain. Only 12% reported being aware of the upcycling approach. Emphasis was placed on the valorization of local raw materials and by-products within a circular economy approach. The collaborative workshop, undertaken with women cooperatives, focused on the co-creation of four food prototypes: almond milk flavored with honey and thyme, a nutritious Rif-inspired smoothie, almond butter enriched with carob and flavored with thyme, and nutritive almond Okara bites with carob, honey, and thyme. The workshop demonstrated a significant impact, with skill enhancement ranging from 30% to 50% across key areas, including upcycling, green innovation, digital marketing, and eco-design. The four developed prototypes provide concrete evidence of the potential of local products and underscore the critical role of collaborative approach in strengthening cooperative capacities, overcoming structural barriers, and enabling active participation in the green transition. Indeed, targeted training programs and workshops in these areas help to bridge existing gaps and enable agri-food cooperatives in thriving in the market while ensuring environmental sustainability.

Keywords— Morocco, Central Rif, women agri-food cooperatives, survey, collaborative workshop, green innovation, eco-friendly prototypes, upcycling, circular economy

I. INTRODUCTION

Ensuring a sustainable and resilient food system is one of the most pressing global imperatives of the 21st century [1]. In this regard, agri-food systems face many challenges at global and local levels, including issues related to climate change, environmental degradation, pollution, loss of biodiversity as well as increasing price fluctuations [2]–[4]. These challenges pose a significant threat to food security, agricultural incomes, livelihoods, and rural development [4]. A shift toward circular food systems offers a promising alternative. In this context, agri-food cooperatives play a pivotal role in anchoring sustainable practices and promoting local products. They constitute a fundamental pillar of rural economies in many countries, serving as vital mechanisms for improving farmers' access to markets, enhancing their bargaining power, and fostering knowledge exchange and innovation [5]–[7]. Despite their significance, these cooperatives face a myriad of obstacles that threaten their long-term sustainability and effectiveness [8]–[11].

Consequently, circular economy has attracted growing interest as a model to address these challenges by reducing resource demand via reuse, repair, remanufacturing, or recycling [12]–[15]. Therefore, green technological innovation is a key requirement for achieving ecological sustainability, providing transformative pathways to address the structural and environmental challenges confronting agri-food cooperatives [16], [17]–[21]. However, despite this growing momentum, existing studies provide limited attention to the adoption of sustainable practices at the small-scale level and insufficiently investigate the integration of green innovation with local product valorization. This research is motivated by the urgent need to identify the constraints, expectations, and innovation potential of women agri-food cooperatives in the Central Rif. It aims to foster innovation through the valorization of local resources and to develop eco-friendly products aligned with sustainable practices. According to the above objectives, the study proposes the two research questions to highlight its novelty:

- i. Which challenges constrain the engagement of agri-food cooperatives in the Central Rif in the innovation process?
- ii. How can the divide between technological innovation and practical needs of local actors be effectively addressed?

II. METHODOLOGY

The research methodology was conducted in two phases to comprehensively address the objectives of the study:

A. Preliminary Survey: Needs Assessment

A semi-structured survey was conducted among women agri-food cooperatives in the Central Rif Al Hoceima province to assess valorization practices, technical constraints, market challenges, and innovation needs. It focused on cooperatives operating in three high-potential sectors namely, beekeeping, aromatic and medicinal plants, and the valorization of local agricultural resources. Stratified systematic sampling method was employed to capture diversity across sector, size, geographical location, and level of market integration. To ensure statistical representativity, the required sample size was calculated based on Cochran's formula, adjusted for a finite population. This study targets 55 cooperatives operating in the Central Rif region. Using a 95% confidence level ($z = 1.96$), an estimated population proportion $p = 0.5$ (maximizing sample size under uncertainty), and a margin of error of 5%, the minimum representative sample size was calculated to be 49 cooperatives [22]. A total of 50 cooperatives were surveyed, providing broad coverage across all defined strata. Data were collected through face-to-face interviews and focus group discussions, allowing both quantitative and qualitative insights. The results were analyzed using descriptive statistics to identify priority areas for product development and capacity building [22].

B. Dual Approach: Laboratory Tests and Collaborative Workshop

Using the survey findings, a dual methodological approach was implemented. The laboratory component focused on the formulation, physicochemical and sensory characterization, and microbiological-evaluation of innovative prototypes. In parallel, collaborative workshop was organized with the cooperatives to co-create eco-friendly products, integrate sustainable practices, validate technical feasibility, and refine formulations through participatory feedback. This combined approach ensured both scientific rigor and socio-economic relevance. For the development of these four prototypes — almond milk flavored with honey and thyme, Rif-inspired nutritious smoothie, almond butter enriched with carob and flavored with thyme, and nutritious almond Okara

bites with carob, honey, and thyme — simple processing methods adapted to local agricultural resources were implemented to ensure the quality, safety, and functionality of the final products (Fig. 1).

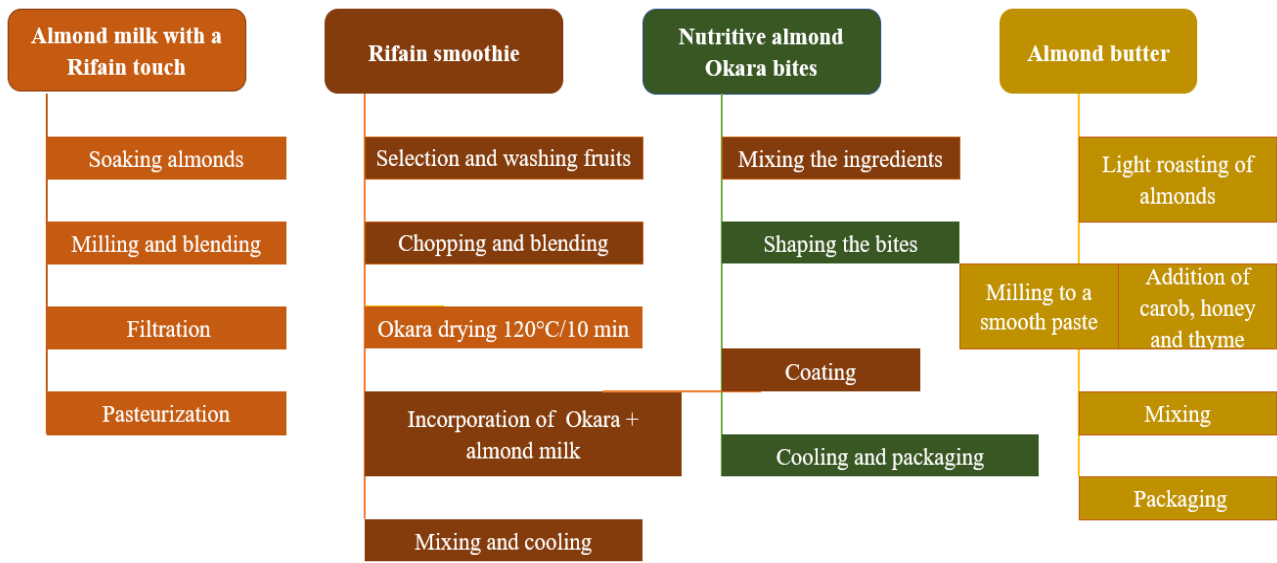


Fig. 1 Overview diagram of the production process and sustainability features of the developed prototypes

III. RESULTS AND DISCUSSION

A. Insufficient Training and Guidance for the Adoption of Sustainable Practices

Among the cooperatives surveyed, 60% reported the absence of targeted training programs that would enable them to implement sustainable practices. Regarding sustainability practices within the value chain, only 16% of the cooperatives demonstrated a high level of awareness of upcycling and had adopted the reuse of residual food, particularly in the production of scrubs, indicating a limited but promising engagement in value addition through by-product utilization (Fig. 2). This widespread lack of tailored capacity-building programs significantly hampers the cooperatives’ ability to integrate ecological innovations into their operations [22].

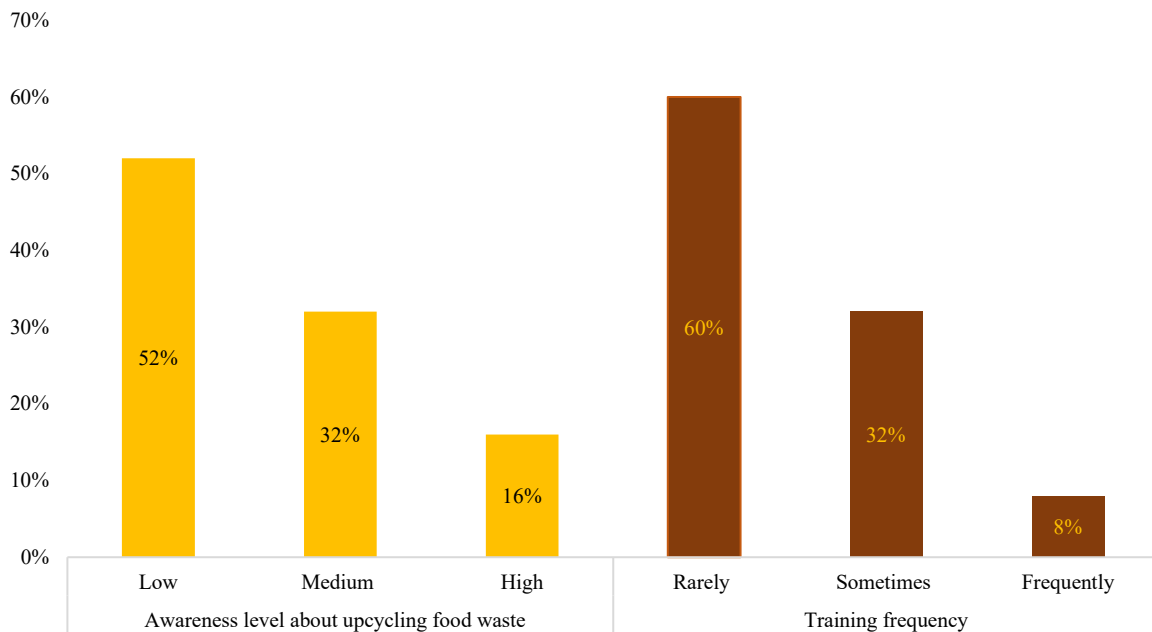


Fig. 2 Impact of training frequency on awareness levels about food waste upcycling

B. Support Needs for the Effective Operation of Agri-Food Cooperatives in the Central Rif

The results regarding the operational support needs of agri-food cooperatives in the Central Rif reveal clearly defined priorities. The development of new product lines and the valorization of waste and by-products emerged as the most pressing needs, reported by 90% of the cooperatives. This emphasis on innovation reflects the cooperatives' desire to differentiate themselves in the market, attract customers, and modernize their practices. Through innovation, they can both refine existing practices by adding creative and attractive elements, optimize the use of local resources, and meet consumer expectations in terms of quality and originality. The need for support in obtaining quality certifications (84%) and in digital marketing (72%) highlights the importance of regulatory compliance, consumer trust, and modernized business practices. The use of digital tools for traceability and quality management (56%) demonstrates the cooperatives' openness to adopting technological solutions to enhance transparency, and competitiveness. Improving existing practices (44%) and the use and maintenance of equipment (62%) remain important needs, though less prioritized, suggesting that innovation and valorization are favored, partly due to the limited availability of training programs in these areas (Fig. 3).

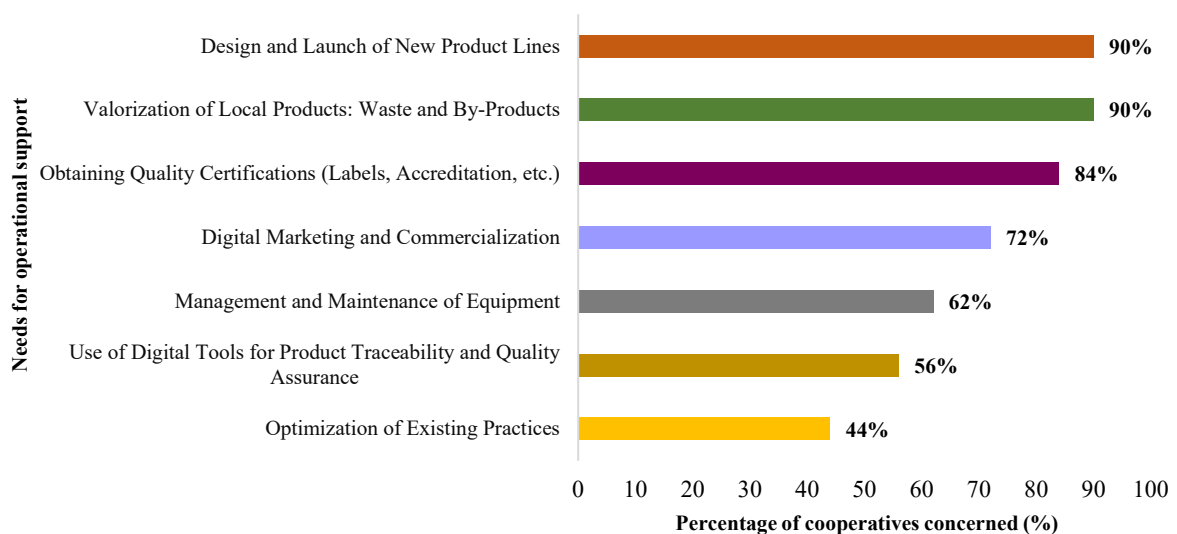


Fig. 3 Key support areas for strengthening the performance of Central Rif agri-food cooperatives

C. Influence of the Participatory Local Product Workshop on the Capabilities and Practices of Central Rif Agri-food Cooperatives

The results of the competency assessment conducted before and after the participatory workshop demonstrate a significant improvement across all targeted knowledge domains. Understanding of eco-design increased from 20% to 50%, representing a 30% improvement, indicating that the workshop enabled the cooperatives to better integrate sustainable design principles into their practices. Regarding product formulation and innovation, the progression was even more pronounced, rising from 30% to 66% (+36%). This substantial increase reflects a marked strengthening of both creative and technical capacities among cooperatives. Awareness of upcycling practices showed a particularly notable improvement, increasing from 10% to 60% (+50%). This remarkable progression demonstrates that the participating cooperatives developed a comprehensive understanding of waste and by-product valorization strategies. Finally, mastery of strategic marketing advanced from 15% to 58% (+43%), reflecting a significant enhancement of skills related to product promotion and commercialization. Overall, these findings highlight the effectiveness of the participatory workshop in strengthening the cooperatives' knowledge and competencies in key areas essential for sustainable development and innovation (Fig. 4).

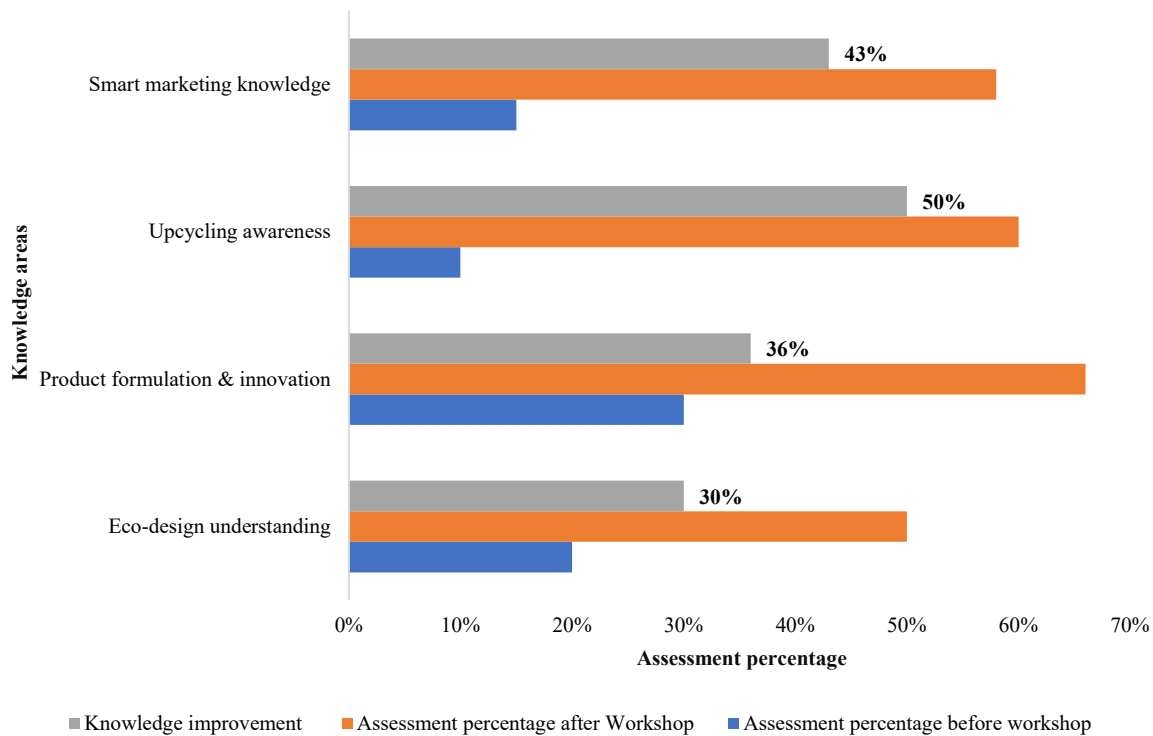


Fig. 4 Effect of the participatory local product valorization workshop on the capacities of agri-food cooperatives in the Central Rif

IV. CONCLUSIONS

This research demonstrated the feasibility and relevance of an innovative and sustainable approach to the valorization of local products and by-products from the Central Rif region. By developing four prototypes based on locally sourced raw materials — notably almond, carob, thyme, and honey — in collaboration with agri-food cooperatives, the study showed that simple, context-adapted, and eco-responsible solutions can be implemented at a small scale to address economic and environmental challenges while responding to current market trends.

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