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Women's Agri-Food Cooperatives Driving Sustainable Innovation: Creating Eco-Friendly Products from Local Resources in Morocco's Central Rif

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***Abstract*— Sustainable innovation plays a crucial role in enhancing *terroir* products visibility, boosting market access, and fostering circular economic growth. In this context, agri-food cooperatives act as key drivers of employment, value creation, and conservation of local food heritage. This study aims to support local eco-friendly innovation in the Central Rif using a combined survey-based and experimental approach both in the research laboratory and in the cooperative unit through a collaborative workshop. It also seeks to highlight the potential of by-products and their role in reinforcing the eco-design approach within agri-food systems. 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 broad and diversified sample of 50 agri-food cooperatives operating in the Central Rif, selected via 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 16% of these cooperatives 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, conducted with women's 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 the 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 to thrive in the market while ensuring environmental sustainability. Furthermore, enhancing consumer awareness regarding the nutritional value of by-products, as well as the contribution of cooperatives, is crucial for accelerating the green resilient transition and promoting eco-friendly product design.**

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

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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]. Accordingly, a shift toward circular food systems offers a promising solution. In addition, consumers tend to be more mindful of their food choices and place greater emphasis on healthy, functional, and nutritious products. New concepts and innovations in healthy and ethically produced foods are emerging in response to these consumer demands [5].

In this context, agri-food cooperatives play a pivotal role in anchoring sustainable practices, meeting consumer needs, 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 [6]–[8]. Despite their significance, these cooperatives face a myriad of obstacles that threaten their long-term sustainability and effectiveness [9]–[12].

Indeed, recent global assessments indicate that a substantial share of food produced for human consumption is lost or wasted along the supply chain. However, updated evidence shows that approximately 19% of food available to consumers is wasted at the retail, food service, and household levels, corresponding to about 1.05 billion tonnes annually. These findings also highlight an important distinction between food loss, occurring during production and post-harvest stages, and food waste, occurring at the retail and consumption stages [13]–[15].

Thus, reducing and better valorizing food waste and by-products has been widely recommended as efficient strategies to maximize the benefits of available resources and improve food security, sustainability, and circularity in food systems [16]–[18].

Consequently, circular economy has attracted growing interest as a model to address these challenges by reducing resource demand via reuse, repair, remanufacturing, or recycling [19]–[22]. Moreover, circular agri-food supply chains intend to mimic natural biological cycles through networks that enhance organic by-products and innovate sustainable business models. Such practices can supplement the value of agricultural products by incorporating sustainability attributes [23].

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 [24], [25]–[29]. From a global perspective, agricultural innovation not only fosters foreign direct investment but also contributes to the development of competitive products, job creation, and increased export revenues within the agricultural sector [30].

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. To address these objectives, the study is guided by the following research questions:

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, medicinal and aromatic plants (MAPs), 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

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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. Given the relatively small target population (N=55), the survey covered 50 cooperatives, representing more than 90% of the population. 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. 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 [31].

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, a 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).

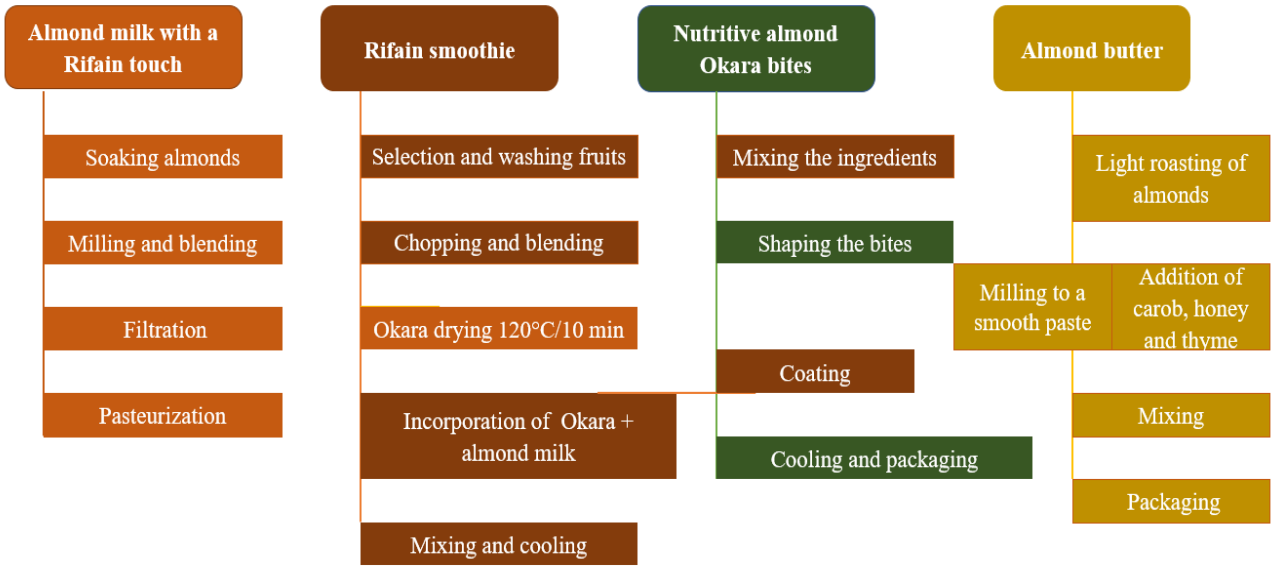

Fig. 1 Overview diagram of the production process and sustainability features of the developed prototypes

III. Results and Discussion

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

Sustainable innovation is defined as the process of creating new products, services, technologies or business models that generate both economic value and positive environmental and social outcomes. It integrates different considerations from generating ideas to research and development (R&D) as well as commercialisation [32].

Globally, food waste accounts for about 8–10% of greenhouse gas emissions, necessitating its reduction [33], [34]. In this situation, developments driven by global technological advancements and a competitive environment can enhance innovations in products, processes, and services in the food industry [35], [36]. One type of innovation is upcycling, which is transforming food lost during the production process into new products, thereby reducing food waste [37].

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The findings showed that 52% of cooperatives reported discarding by-products, treating them as waste rather than valorizing them, indicating significant untapped opportunities for waste valorization and circular economy approaches (Fig.2).

Among the cooperatives surveyed, 60% reported the absence of targeted training programs that would enable them to implement sustainable practices and boost their ecological systems. 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, soaps 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 [31].

As a result, this lack of training has a direct impact on the visibility of women's cooperatives of Central Rif in the market. It restricts the diversity of their product offers and limits their growth. Indeed, sustainability and innovation pave the way for economic progress and consumer trust. They promote the *terroir* products and participate in the progress of rural areas.

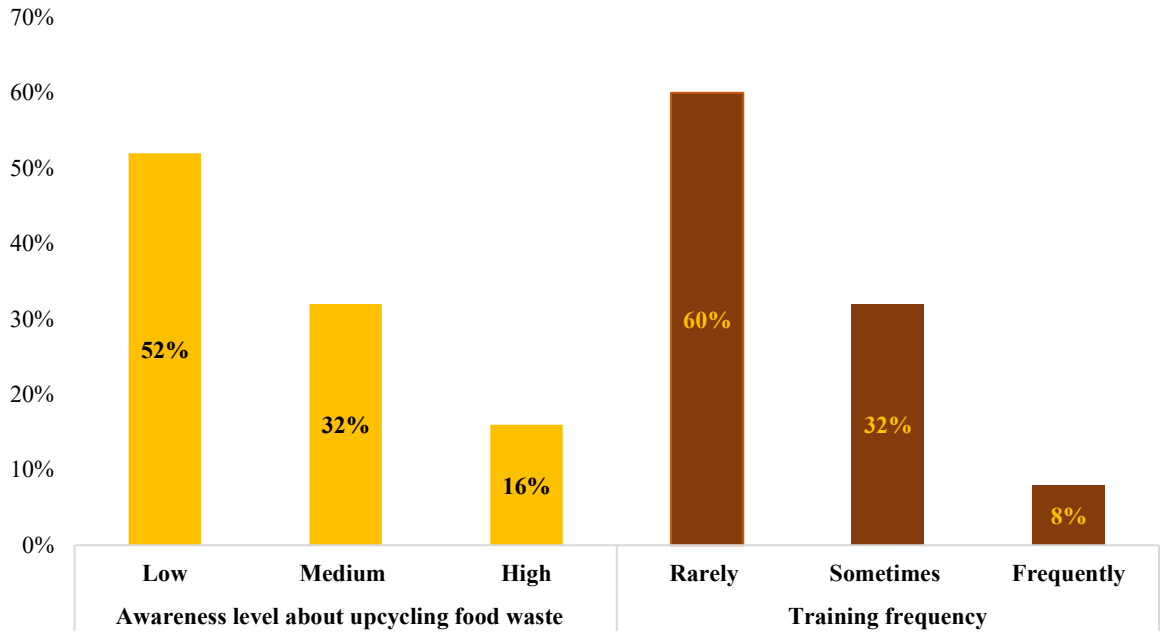

Fig. 2 Relationship between training exposure and awareness of food waste upcycling practices

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. According to the FAO [38], certifications are crucial for ensuring the safety of agricultural products. However, training and capacity building should be extensively tailored to assist agri-food cooperatives in implementing food safety standards and mitigating health hazards [38].

The use of digital tools for traceability and quality management (56%) demonstrates the cooperatives' openness to adopting technological solutions to enhance transparency, and competitiveness, while improving existing practices (44%) and the use and maintenance of equipment (62%) remain important needs, though less

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prioritized, suggesting that innovation and valorization are favored, partly due to the limited availability of training programs in these areas (Fig. 3).

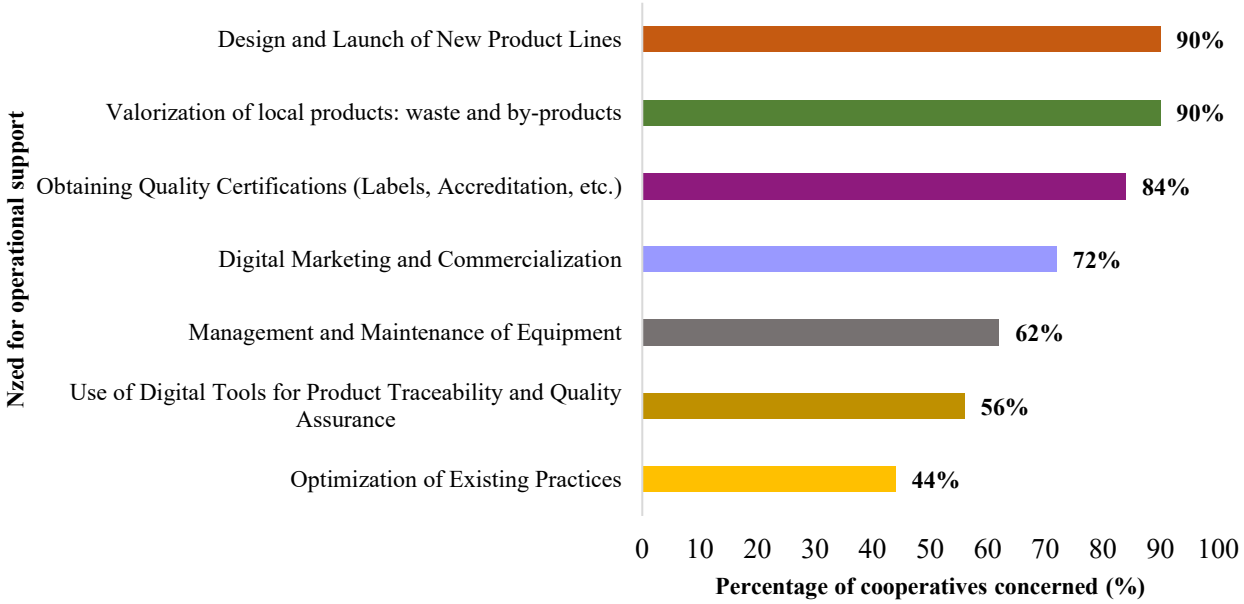

Fig. 3 Key support areas for strengthening the performance of Central Rif agri-food cooperatives

C. Assessment of By-Product Valorization Practices of Agri-Food Cooperatives in the Central Rif

Plant-derived waste and by-products, such as peel, leaves, seeds, bran, kernel, pomace, and oil cake can be obtained from a wide variety of fruit, vegetables, cereals, oil crops, root and tubers and other legumes during the primary production and the subsequent processing and distribution stages [39]–[41]. Growing research shows that such waste and by-products can be valorized by the extraction of valuable nutrients and compounds, such as proteins, vitamins, fatty acids, amino acids, dietary fibers, flavonoids, and phenolic compounds, among others [42]–[45]. The extracted components and bioactive compounds have been reported to have several health-promoting properties against various diseases such as diabetes, cancer, and cardiovascular and neurocognitive diseases, mainly due to their antioxidant and antimicrobial activities [46], [47]. Such components have already found applications in a vast array of products such as functional beverages, nutrient-enriched snacks, and food supplements [48]–[50].

The results of the survey illustrate that 48% of cooperatives in the Central Rif underestimate and do not valorise their by-products, suggesting that nearly half of the surveyed structures are not yet exploiting the economic and environmental potential of their agricultural local residues. Among the valorization practices reported, cosmetic applications (16%) represent the most common alternative use of by-products. Cooperatives produce value-added products such as scrubs, creams, and soaps, exhibiting growing interest in diversifying income sources through natural and locally derived ingredients (Fig. 4). This idea of reuse is part of a broader concept known as circular economy. It replaces the idea of linear economy and is based on reintroducing materials into the industrial process, combining activities of reduction, reuse, and recycling of materials [51]. Furthermore, the strategy of the circular economy preserves the value of the initial material and reintegrates it into the economic cycle before it becomes waste. This approach preserves the value of the initial product and reduces the amount of energy and raw materials used [52].

Non-food products, particularly candles (12%), and composting (10%) were also identified as valorization pathways. These practices contribute to waste minimization while generating additional products or improving soil fertility. The use of by-products for animal feed accounted for 8%, reflecting a practical approach to resource efficiency by reintegrating residues into livestock production systems. In contrast, only 6% of cooperatives reported using by-products for basic processing activities such as drying, grinding, and packaging, while none (0%) engaged in food innovation using by-products (Fig. 4).

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The absence of eco-friendly food innovation may be attributed to a poor awareness of the nutritional, functional, and economic value of the by-product resources, as well as limited knowledge regarding their potential applications in the development of innovative food products.

Agri-food by-products, e.g., peels, pomace, seeds, spent grains, shells, bran, organs and whey, are increasingly explored as sources of nutrients and bioactive compounds for the recovery of components such as food ingredients, food enzymes and food additives [53]–[57]. Increasing the awareness of cooperatives regarding these by-products is essential to foster green innovation and support their transition toward sustainable resilient value-added production.

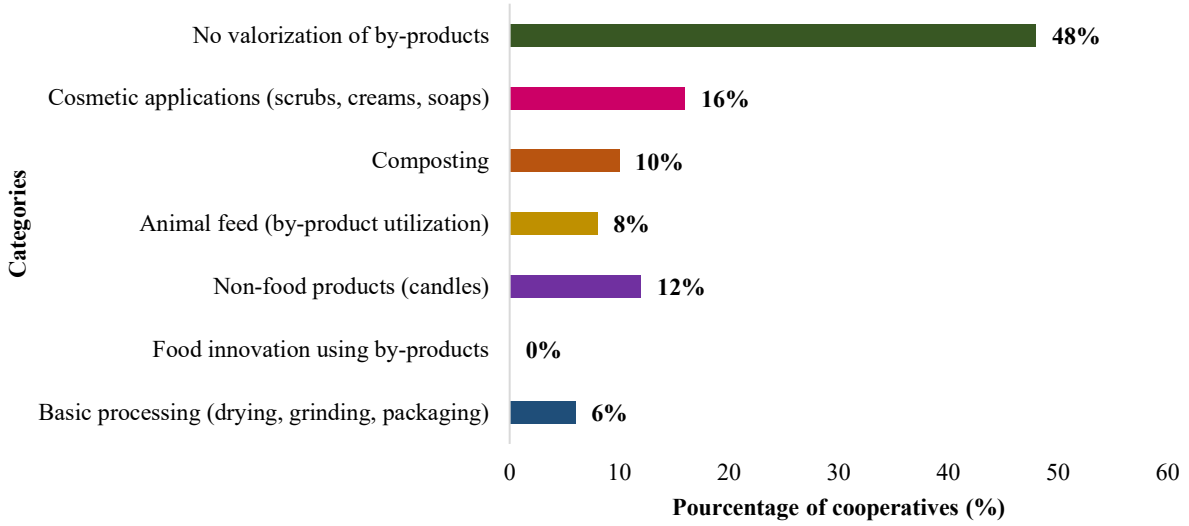

Fig. 4 By-product valorization practices adopted by agri-food cooperatives in the Central Rif

D. Conception of Eco-Friendly Prototypes from Central Rif Local Resources and Their Impact

The development of the 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 —demonstrated the feasibility and benefits of integrating by-products as ingredients in new food product formulations, thereby contributing to product diversification and better alignment with consumer needs and expectations. The utilization of almond Okara, generated as a by-product during almond milk filtration, enabled the establishment of a circular production approach, promoting the valorization of by-products and substantially reducing processing losses. Furthermore, the study emphasized the importance of inter-cooperative collaboration across different sectors to facilitate access to raw materials and reduce logistical costs.

Additionally, stakeholder engagement plays a crucial role in driving innovation in the industry, with a focus on product innovation for achieving superior value. Small businesses in this sector can enhance their competitive position through process innovation activities [58].

Another important aspect is the consideration of consumer perspectives. Understanding consumer reactions is vital for the effective development of new food products [59]. While food technologists emphasize the importance of innovative food, such as increased effectiveness and quality [60], consumers are often sceptical of new technologies, which can reduce acceptance [61]. This problem calls for the need for consumer-focused strategies to support the long-term uptake of new food products [62]. Perceived value significantly influences consumers' attitudes and likelihood of repeat purchases of the food. However, the perceived value of upcycled products may decrease because of the relationship with waste or inferior quality [63], [64].

To address this challenge, it is essential to encourage cooperatives to develop formulations that align with consumer needs, while raising awareness of upcycled products and carefully selecting appropriate terminology to describe them. The names of the four prototypes were deliberately chosen to reflect the identity of the rural

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region and to promote local products and nutritional aspects, three factors that may enhance the acceptability of eco-friendly products.

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

The transfer of competencies from the laboratory to the cooperatives helped participants better understand more deeply the purpose of sustainable innovation and their role in the shift towards resilient food systems.

The results of the competency assessment conducted before and after the participatory workshop provide evidence of 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%. This substantial increase reflects a notable strengthening of both creative and technical capacities among cooperatives. Awareness of upcycling practices showed a particularly marked improvement, increasing from 10% to 60%. This remarkable progression demonstrates that the participating women's cooperatives developed a comprehensive understanding of waste and by-product valorization strategies. Finally, mastery of strategic marketing advanced from 15% to 58%, 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. 5).

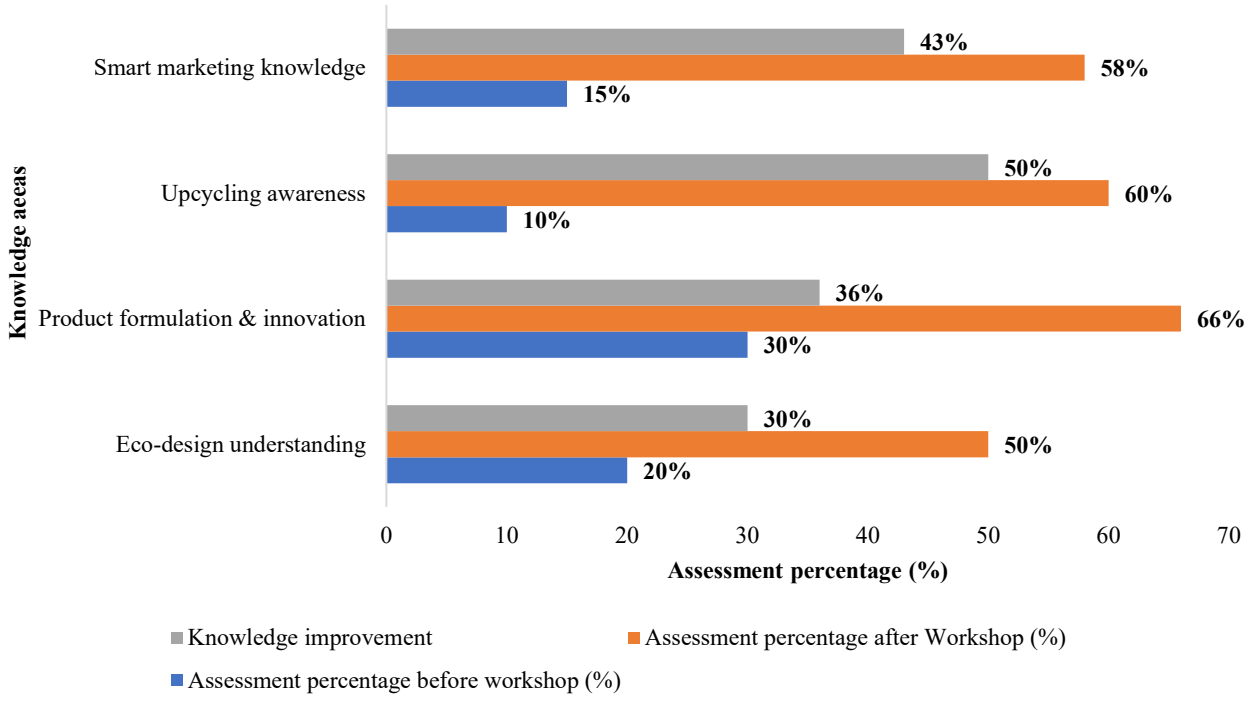

Fig. 5 Effect of the participatory local product valorization workshop on the capacities of agri-food cooperatives in the Central Rif

IV. CONCLUSIONS

Women's cooperatives play a vital role in ensuring sustainable food systems and empowering rural areas. Yet, to facilitate the transition and boost the eco-friendly valorization of local resources, it is imperative to strengthen their capacities and awareness.

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

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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.

Strengthening collaboration between researchers and women's cooperatives is crucial for facilitating knowledge transfer and accelerating the shift toward sustainable resilient food systems. Through demonstrative workshops and hands-on training, cooperatives can better recognize the value of by-products and their potential for food innovation, clean cosmetic formulations, their role as functional ingredients, and the value-added product development.

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