VIEWPOINT

Special Issue - Potential of food by-products

Potential of Food By-Products

Contribution of Academic End-of-Studies Projects to the Startup Initiative Adopted by the Ministry of Higher Education and Scientific Research: The Case of the Valorization of Agri-Food Industry By-Products in Algeria

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1 INTRODUCTION

According to the Industrial Production Index (IPI) of the National Statistics Office (ONS), the agri-food sector shows a notable dynamic, as evidenced by the data from the first quarter of 2024, which reveals a significant positive variation of +10.7%. This progression is mainly attributable to the robust performance of the dairy industry sector, which showed a remarkable growth of +27.6%, and to the substantial expansion of animal feed production, which experienced a spectacular jump of +74.7%, contrasting with a substantial decrease of 29.9% observed during the same period the previous year. Nevertheless, the cereal processing sector shows a divergent trajectory, recording a decline of 3.6% compared to an increase of 8.7% in the last year (ONS, 2024).

In terms of considering the rise in the agricultural food industrial production index as a key driver of economic development. It is important to take into consideration that it leads to the production of vast amounts of organic and inorganic industrial waste from various sources, where the by-products of the agricultural food industry sector represent a significant portion of this waste. Due to their undesirable characteristics, they actually pose a dual challenge, both environmentally and economically (Rațu *et al.*, 2023). From an environmental perspective, these products significantly contribute to rising pollution levels. Improper disposal of them results in air, water, and soil contamination. For instance, discharging liquid waste into water bodies harms aquatic ecosystems, while solid waste can pollute the soil, reduce its fertility, and cause poisoning. Economically, managing and safely disposing of these wastes incurs high costs, representing a substantial drain on resources. However, these by-products also hold hidden economic potential, as they can be transformed into new resources through recycling and valorization, which can be utilized in other manufacturing processes. These methods also promote energy conservation, generate new job opportunities, and reduce the

need to harvest raw materials, thus benefiting both the economy and the environment (Roleders *et al.*, 2024; Ukaogo *et al.*, 2020). Waste from the agri-food industry can provide a variety of "by-product" substances that may boost the nutritional value and functionality of new products. These substances often contain high levels of proteins, dietary fibers, lipids, vitamins, polyphenols, phytosterols, and lignans. Examples of waste that improve the health benefits of new products include fruit and vegetable pomace, post-extraction flour or pulp, molasses, and other by-products. These materials can also be used as substrates for manufacturing pharmaceuticals, cosmetics, dyes, vitamins, or other bioactive substances (Chaalal *et al.*, 2020; Kowalski & Gumul, 2024).

Within the framework of the circular economy, valorizing by-products and managing them effectively are the best solutions, as this strategic approach has recently gained increasing interest from many countries worldwide to strengthen their circular economies (Rațu *et al.*, 2023). In this context, the initiative of business incubators and graduation projects under the title "Startup Foundation," adopted by the Ministry of Higher Education and Scientific Research in Algeria, provides a pathway for the academic community to contribute to the valorization of by-products from agricultural food industries. This initiative offers a unique opportunity to connect academic solutions, represented in study projects, with national needs, thus supporting the development of the country's circular economy. This point of view aims to examine the role of academic end-of-study projects in this initiative, identify the practical and regulatory challenges they encounter, and propose an effective framework to activate this role efficiently, considering all stakeholders.

2 Food Industry Sector in Algeria: Economic Significance and Leading Industries Producing By-Products

The agri-food industry has seen substantial growth in recent years in Algeria, playing a vital role in the national economy. This sector employs 1.6 million people, accounting for 16% of the active workforce, and contributes 47.68% of the gross output and 38.4% of the value added to the national industry (Ounnaci *et al.*, 2024). Due to the lack of official statistics or academic research, it is impossible to identify which food industries dominate in Algeria or the share of each. Additionally, the absence of accurate data on food industries and the by-products generated by each sector is a major obstacle to systematic valorization efforts. Nevertheless, based on the brands of leading producers, the industries listed in Table 1 have a significant presence.

Table 1. The Most Prominent Agricultural Food Industries and their Brands in Algeria

Industrial Product Category	Brand (Main)	Example of Potential By-products
Sugar, Vegetable Oils, Margarine	*Cevital and Afia*	Molasses, bagasse, oilseed meal
Pasta	*Sim, Extra, and Benamor*	Wheat bran and germ (from milling), dough scraps
Sodas and Juices	*Rouiba, Hamoud Boualem, etc.*	Fruit pomace (peels, seeds, and pulp)
Milk and Dairy Products	*Soummam, Danone, Candia et Giplait Group*	Whey, buttermilk, cheese scraps
Meat Products and Delicatessen	*Hadjout, Bellat, etc.*	Bones, fat, hides, blood

3 By-products From the Food Industry: A Strategic Resource For the Circular Economy

During various stages of manufacturing, the food industry produces enormous quantities of by-products each year, estimated at over 190 million tons. These include a wide range of materials such as damaged raw materials, fruit pomace, leaves, seeds, peels, bran, oilseed cakes, and molasses (Enciso-Martínez *et al.*, 2024). Traditionally, these materials were considered waste, posing significant environmental challenges because of their large volume and high-water content, which encourages microbial growth (Raza *et al.*, 2021). According to the Food and Agriculture Organization (FAO), approximately 1.3 billion tons of food are lost or wasted annually, underscoring the magnitude of this issue (Beuving *et al.*, 2024). Table 2 offers an overview of the potential sources of these by-products and waste generated during various food manufacturing processes. The actual value of these by-products lies in their chemical properties and rich nutritional content, making them a valuable resource rather than mere waste. For example, plant-based by-products are high in carbohydrates, proteins, phytochemicals, and antioxidants.

Fruit and vegetable residues also contain substantial amounts of dietary fiber and bioactive compounds (Cecilia *et al.*, 2019). This rich composition makes them suitable for valorization and use in various applications, supporting the transition toward more sustainable food systems and the adoption of circular economy models that reincorporate these materials into production chains (Ligarda-Samanez *et al.*, 2025; Reguengo *et al.*, 2022). For instance, China produces 20 million tons of soybean residues annually (Rashwan *et al.*, 2023).

Table 2. Potential Sources of Agri-Food By-Products and Waste from Food Processing and Production

By-products sources	By-products and Wastes	Examples
Fruit Processing	Fruit pomace, Fruit peels, Fruit seeds.	Apple pomace, Citrus peels, Grape seeds, and Others.
Dairy Processing	Milk residues, Cheese residues, Yogurt residues, Butter residues.	Whey, Cheese remnants, Yogurt remnants, Butter remnants, and Others.
Meat, Fish, and Egg Processing	Animal bones and skins, Fish bones and skins, Slaughter blood, Meat fat and scraps, Eggshells.	Beef bones, Chicken skins, Fish remnants, Chicken blood, Pork fat, Eggshells, and Others.
Vegetable Processing	Tomato pomace, Beet and carrot residues, Potato and sweet potato residues, Cucurbit wastes, Onion and garlic peels.	Tomato pomace, Beet leaves, Potato peels, Pumpkin peels, Onion peels, and Others.
Cereal Processing	Wheat bran and germ, Corn germ and grits, Soybean meal, Soybean hulls, Quinoa residues.	Wheat bran, Corn grits, Soy meal, Soy hulls, Quinoa waste, and Others.
Sugar Production	Sugarcane bagasse, Molasses, Beet pulp, Sugarcane tops and leaves, Sugar beet tops and leaves.	Sugarcane bagasse, Molasses, Beet pulp, Beet leaves, and Others.

The strategies and applications of food by-products are numerous, aiming to transform them into value-added resources. One of the most prominent applications is their direct integration into food products to enhance their nutritional value and sensory properties, such as adding apple powder to yogurt or incorporating fibers and antioxidants into baked goods, meats, and beverages. Active compounds can also be extracted from them for use as natural preservatives, such as those found in citrus peels. Furthermore, the applications extend to other vital fields, where they are used as livestock feed, organic fertilizers, and soil enhancers in agriculture, or in the production of bioenergy (biogas). Figure 1 illustrates these diverse applications, which also include the pharmaceutical and cosmetics industries, as well as bio packaging, highlighting the immense potential of these resources in building a circular and sustainable economy.

4 SWOT Analysis of Opportunities For Transforming Academic End-of-Study Projects into Startups in the Field of Byproduct Valorization

To evaluate the true potential and challenges of turning graduation projects into startups that focus on valorizing food industry by-products in Algeria, a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) serves as an appropriate strategic tool (Namugenyi *et al.*, 2019).

4.1 Strengths

This initiative is built on a set of internal strengths that provide a strong foundation for its success. First, support from the government and institutions is emphasized in the regulatory framework established by Decree No. 008 dated February 23, 2025, which updates and expands Decree No. 1275 dated September 27, 2022. This decree details the procedures for preparing an end-of-study project for a university degree—specifically, a startup created by students at higher education institutions—a process that encourages and legitimizes turning these projects into economic entities. Government support extends beyond regulatory and legislative measures; it also offers guidance to the targeted group through business incubators found at all higher education institutions. The second strength is the relative abundance of raw materials (by-products) at low or minimal costs, which can significantly reduce the initial expenses associated with starting and executing projects on the ground. Third, the local market's capacity to absorb such emerging projects is a key advantage. Additionally, the plentiful young and enthusiastic student talent is a vital human resource, capable of adopting innovative ideas and eager to implement them with passion.

4.2 Weaknesses

Despite its strengths, the initiative faces key internal challenges. The first weaknesses come from the obvious lack of entrepreneurial experience among many supervising professors; although they possess high academic competence, they may lack practical skills in business management and development. While the support provided by business incubators to students is seen as a strength, their current form remains a significant weakness, especially regarding the duration and quality of training. Additionally, the weak structural and collaborative connections between the university and the industrial sector hinder technology transfer and understanding of real market needs. The lack of accurate statistical data on the quantities and types of by-products available geographically, along with the absence of a risk-taking culture in the academic environment, limits students' ability to make informed investment decisions and pursue ambitious projects.

international organizations that support green and sustainable



Figure 1. Potential Applications of Agri-Food By-Products

4.3 Opportunities

The external environment presents promising opportunities that can be used to advance this initiative. The most notable of these is the global movement toward sustainability and the circular economy, which is creating a growing market for eco-friendly products and increasing consumer acceptance of them. This trend also opens the possibility of securing funding from national and projects. Locally, there is a growing demand for innovative, locally made products, accompanied by expansion in the agricultural sector and the government's efforts to promote it, as well as the development of manufacturing industries. Additionally, ongoing advancements in processing and extracting secondary products provide these startups with the opportunity to address market gaps and offer alternatives to imported goods.

4.4 Threats

Many external threats and obstacles need to be considered. Logistical challenges are among the most significant, including the mechanisms and processes for collecting by-products from their sources, storing them, and transporting them, which require infrastructure and coordination that may not be available. The presence of unclear or strict laws and regulations regarding the health safety of recycled products also presents a business risk and a potential barrier that could delay or prevent the introduction of new products to the market. Lastly, fluctuations in the quality and availability of raw materials, which are influenced by seasonal variations and industrial production processes, pose a threat to production continuity and the consistency of the final product's quality.

5 Practical and Regulatory Challenges in the System of Valorizing By-Products and the Role of Stakeholders

Moving from an academic project idea to a successful startup in by-product valorization requires more than just entrepreneurial motivation; it involves navigating a complex, practical, and regulatory environment. Achieving success in this area demands a thorough understanding of these challenges and active participation from all stakeholders within an integrated system.

5.1 Technical and Logistical Challenges

These obstacles are among the most significant challenges startups face immediately. Difficulties begin at the collection stage, as by-products are often geographically dispersed and decentralized, which increases transportation costs and requires high coordination. Storage is another challenge, as the perishable nature of many of these materials (due to their high-water content) necessitates rapid processing or specialized infrastructure, such as refrigeration or drying, to prevent microbial degradation. Additionally, the cost of pre-treatment to extract valuable compounds can be high. The biggest hurdle, however, is transitioning from laboratory-scale to industrial-scale production (scale-up). Processes that succeed on a small scale in the lab may fail or become uneconomical when scaled up for industrial use, which demands specialized engineering and technical expertise.

5.2 Regulatory Framework and Safety Standards

Gaps and lack of clarity in the legislative and regulatory frameworks for using recycled by-products pose a significant obstacle to their commercialization. Startups need a clear legislative framework that outlines the health and safety standards required for these products in the food chain, whether as direct food, additives, or animal feed. Without these standards, there is legal uncertainty, licensing becomes difficult, and consumer confidence drops, making it nearly impossible to enter local markets or access export opportunities.

5.3 Role of Stakeholders in the System

These challenges cannot be addressed through individual efforts alone; instead, they require the collective action of a network of key stakeholders.

Academic supervisors must evolve their role from solely providing academic guidance to also offering entrepreneurial mentorship. In addition to managing the technical aspects of the project, they should assist students in developing viable business models, understanding market fundamentals, and protecting intellectual property.

University laboratories and incubators serve as a vital bridge between scientific research and the market. They are responsible for providing the necessary infrastructure for initial experiments and prototype development, as well as offering technical support and specialized consultations. Incubators also play a crucial role in providing entrepreneurship training and connecting students with experts and potential investors.

Industrial partners. They play an essential role in the success of these projects. Not only are they the primary and reliable source of raw materials (by-products), but they also provide valuable practical expertise on market requirements and industrial quality standards. Industrial partners can act as “first customers” or help test the product on a semi-industrial scale, thereby reducing investment risks and accelerating the commercialization of the final product.

6 Conclusions and Perspectives

In conclusion, agri-food by-products are considered an important economic resource that should not be overlooked, particularly in Algeria, where they are seen as an easily accessible and low-cost pillar for students wishing to create start-ups. This makes the End-of-studies projects and Diploma Initiative, titled Startup Project, adopted by the Ministry of Higher Education and Scientific Research, an important opportunity to contribute to valorizing and recycling various types of agri-food by-products from the food industries. In this context, we would like to comment on several points and offer some suggestions that we believe will improve the effectiveness of the Ministry of Higher Education's initiative.

- Improving the clarity and distribution of regulatory decrees and guidelines among students and academics, making them more professional, simple, and easy to

understand. For example, Clause 5 of Decree No. 008 of February 23, 2025, states that students have the right to propose their own project ideas. However, this is not fully reflected in practice due to the lack of early awareness of these laws.

- The same decree (Clause No. 5) explicitly emphasizes the importance of training students in entrepreneurship and integrating them into business incubators. However, there are no clearly defined programs that specify how this integration should be done, including the relevant university levels, duration, and type of training. In this context, we believe that entrepreneurship training and integration into business incubators should be an independent and parallel component of all higher education levels, starting from the first academic year (during the vacation period or after official academic periods). This should involve developing a suitable and effective training plan and programs, as well as creating incentive mechanisms such as making this training a criterion or offering financial incentives like additional scholarships.
- Entrepreneurial training, as previously noted, focuses on students and completely ignores supervising professors and academic project managers. This creates a significant gap. Although they have experience in their academic fields and possess scientific and technical knowledge, most higher education professors lack an entrepreneurial background. Therefore, it is important to include this group in entrepreneurial training by providing systematic training plans and programs, as well as developing appropriate incentive systems—such as exemptions, reducing teaching hours, or offering trips on official holidays as rewards.
- Clause 3 of Decree No. 008 outlines two options for submitting the final thesis. The first is the traditional academic approach. The second involves presenting a comprehensive portfolio or a presentation in the form of an economic model or an economic and technical paper, aimed at improving the study and understanding of the feasibility of project implementation in the field by students. In this context, we believe that the presentation and discussion of projects should focus more on the economic and technical aspects rather than the theoretical or scientific background of the project, with the supervising professor's evaluation of the theoretical, technical, and scientific knowledge of the project idea being the primary responsibility.
- Graduation (end-of-study) projects are currently discussed with professors or trainers specializing in entrepreneurship and active economic partners as members of the discussion committee. This is a positive step for guiding and directing students in their future endeavors. However, we believe that these parties should be involved from the very beginning of graduation projects as essential and necessary supervisory assistants.
- Like other graduation projects, end-of-study projects with a start-up character are typically launched during the last semester of the Master's degree (the second and final year). This period is often insufficient, so we believe these projects should ideally be initiated in the first year of the Master's phase. Doing so would give students and supervisors more time to develop a deeper understanding of their projects, build theoretical frameworks, gather scientific material, study and explore the target market, and prepare a comprehensive feasibility study.
- We emphasize the importance of raising awareness and clarifying everything related to this initiative, including its regulations, decrees, and objectives. It is important to focus on involving scientific and cultural clubs, as well as student organizations. Engaging economic partners, developing more cooperative programs, and improving communication between them and academic institutions—such as organizing lectures, workshops, and discussions—would create a positive influence in this area.
- Providing statistical and market data on the actual number of active enterprises, their geographic distribution, production volume, economic value, and their response to environmental constraints, etc., is a crucial foundation for encouraging the trend toward start-up projects.
- Encouraging and supporting successful projects implemented on the ground through government support, such as offering concessions or tax exemptions during the first years of these institutions, as well as appreciating the efforts of key supervising professors and creating respected and effective incentive systems. It's also important to ensure coordination between the relevant ministry and other relevant government ministries to strengthen and establish comprehensive legislative frameworks for all aspects related to these institutions.

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