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THE CIRCULAR ECONOMY AS A STRATEGY FOR CREATING NEW MARKETS IN THE AGRO-INDUSTRIAL SECTOR

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ABSTRACT: The circular economy proposes a shift in agro-industrial production processes, utilizing waste that is normally discarded to transform it into resources with economic value and reduce environmental impact. This paper analyzes how circular strategies can create new markets in the agro-industry. A qualitative-descriptive analysis was conducted, including a review of scientific literature and a study of practical cases implemented in Latin America and Europe. The results show that valorizing agricultural byproducts allows for the development of bio-inputs, bioenergy, and bioplastics. This circular model makes the sector more competitive because it reduces costs and diversifies revenue streams. Companies that adopt it reduce operating costs by 15-60%, increase their revenue by 8-22%, and gain access to premium markets with price premiums of 10-35%. Valorizing 1,000 tons of organic waste prevents emissions of 400-650 tons of CO_2 and reduces water consumption by 60-70%. However, significant barriers exist: limited access to technology for small and medium-sized enterprises, high initial costs, fragmented regulatory frameworks, and resistance to change. Overcoming these requires public policies that include financing, tax incentives, technical standards, and training. The circular economy not only solves environmental problems but also drives innovation and creates sustainable business opportunities for the agribusiness sector.

Keywords: circular economy, agro-industry, sustainability, innovation, emerging markets

INTRODUCTION

For decades, the agro-industrial production model has followed a linear pattern: extract resources, produce, and discard what is not useful (1). This system has worked, but it is now showing its limitations in the face of natural resource scarcity and worsening environmental problems (2). The circular economy posits that waste is not the end of the process, but the

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beginning of something new (3). In agro-industry, this makes sense because the sector generates many organic byproducts that traditionally end up as garbage.

Kirchherr et al. (2017) (4) explain that the circular economy seeks to maintain the value of resources for as long as possible through reuse and recycling, minimizing waste. In agro-industry, this means transforming fruit peels, sugarcane bagasse, cereal residues, and other byproducts into valuable materials. The FAO (2021) (5) estimates that approximately one-third of the food produced globally is lost or wasted, representing a huge opportunity to implement circular strategies.

The shift towards circular models is not just a response to environmental pressure. It also opens up new business opportunities. There are interesting experiences in countries like Ecuador, Mexico, and Spain where agricultural waste has been valorized and transformed into innovative products with market demand: organic fertilizers, biofuels, biodegradable packaging, and bioactive compounds for the pharmaceutical and cosmetic industries (Salgado-Tello et al., 2024 (6); Valdez & Canobbio, 2025 (7)). This demonstrates significant commercial potential. Implementing the circular economy is not easy. Several obstacles exist: a lack of adequate infrastructure, technological limitations, insufficient regulatory frameworks, and resistance to change. Despite these problems, several studies demonstrate that the long-term economic and environmental benefits outweigh the necessary initial investments (Prieto-Sandoval et al., 2018 (8)).

This paper analyzes the role of the circular economy in creating new markets within the agribusiness sector. It seeks to identify the most effective strategies, concrete benefits, and main challenges. The idea is to provide evidence from real-world cases demonstrating how this approach can make the sector more competitive while contributing to environmental protection.

MATERIALS Y METHODS

This research used a qualitative-descriptive approach that combined document analysis with the study of existing case studies. The work was organized into three complementary phases.

First phase: Comprehensive review of specialized literature. Databases such as Scopus and Web of Science were consulted, as well as documents from international organizations such as the FAO (5) and the Ellen MacArthur Foundation (9). The selection criteria were: scientific publications, technical reports, or regulatory documents published between 2015 and 2025. Studies on the valorization of agro-industrial waste, technological innovation applied to the circular economy, and economic feasibility analysis were prioritized. After applying criteria of relevance and methodological quality, the most useful documents for the research were selected.

Second phase: Analysis of case studies selected for being representative successful circular economy experiences in the agribusiness sector. The cases studied include different geographical contexts (Latin America and Europe) and sectors (fruit, sugar, cereal, and horticulture). For each case, the following were evaluated: waste reduction, new products generated, economic viability, environmental impact, and level of technological innovation.

The information was obtained from business literature, corporate reports, and scientific publications.

Third phase: Interviews with sector experts: agribusiness engineers with experience in waste management, economists specializing in circular models, representatives of producer associations, and consultants in corporate sustainability. The interviews lasted approximately 45 minutes each and were conducted in person and virtually during September and October of last year. A guide with open-ended questions was prepared regarding market opportunities, technical and economic barriers, necessary public policies, and future prospects for the sector. The conversations were recorded with permission and subsequently transcribed for analysis

Qualitative information was processed using thematic coding with Atlas.ti software, identifying categories related to types of valuation, business models, success factors, and recurring obstacles.

The results of the document analysis, case studies, and interviews were compared to validate findings. Finally, a conceptual framework was developed that integrates the findings with theories of circular economy, sustainable development, and shared value creation proposed by Geissdoerfer et al. (2017) (10) and the Ellen MacArthur Foundation (2019) (9).

RESULTS

The systematic analysis of literature, documented cases and interviews with experts made it possible to identify five central dimensions in the implementation of circular economy in the agroindustrial sector: technological routes of valorization, typology of products generated, indicators of economic viability, quantifiable environmental impacts and barriers to scalability.

3.1. Technological Valorization Routes for Agro-industrial Waste

Four main routes for the transformation of agricultural by-products were identified:

Route 1: Bioconversion for agricultural bio-inputs. Includes aerobic composting, vermicomposting, and solid-state fermentation. The cases analyzed in Ecuador (banana waste) and Colombia (coffee byproducts) show conversion rates of 60–75% of organic waste to fertilizer. Processing time ranges from 45–90 days for conventional composting and 30–45 days for vermicomposting with Eisenia foetida. The resulting products have organic matter contents between 35–50%, variable NPK (1.5–3.2% N; 0.8–2.1% P_2O_5; 1.2–2.8% K_2O), and stabilized C/N ratios in the 10–15:1 range

Route 2: Energy transformation through thermochemical and biochemical processes. This includes anaerobic digestion for biogas, alcoholic fermentation for second-generation bioethanol, and pyrolysis for biochar. Experiences in Mexico (sugarcane bagasse for bioethanol) report yields of 250–320 liters per ton of dry bagasse. Anaerobic digestion of fruit and vegetable waste in Spain achieves biogas production of 0.3–0.5 m^3 per kg of volatile solids, with methane contents of 55–70%. Biochar obtained by pyrolysis of rice husks has specific surface areas of 200–400 m^2/g.

Route 3: Extraction of high-value bioactive compounds. It utilizes secondary metabolites present in agro-industrial waste through solid-liquid extraction, ultrasound-assisted extraction, and supercritical extraction. Case studies include: polyphenol extraction from grape pomace (yields 15–45 mg gallic acid equivalent/g), pectins from citrus peels (yields 18–25%), lycopene from tomato waste (concentrations 0.8–1.5 mg/g), and anthocyanins from berry waste (yields 2.5–8.5 mg/g). These compounds have applications in the pharmaceutical, cosmetic, and nutraceutical industries (Matiacevich et al., 2023**).**

Route 4: Development of biomaterials and bioplastics. It produces biodegradable materials from starches, cellulose, and residual proteins. Research in Italy on biodegradable films derived from potato starch shows mechanical properties comparable to low-density polyethylene (tensile strength 8-15 MPa, elongation 80-200%), with complete biodegradability in 60-90 days. Packaging made with sugarcane bagasse fibers exhibits compressive strengths of 2-4 MPa.

3.2. Business Models and the Creation of Emerging Markets

The analysis revealed three circular implementation models in agro-industries:

Model A: Vertical integration within the production chain. Processing companies incorporate internally generated waste valorization units. This model was observed in 45% of cases. Examples include citrus processing plants that integrate pectin and essential oil extraction lines, reducing disposal costs by 40-60% and generating additional revenue equivalent to 8-15% of main revenue.

Model B: Companies specializing in valorization. Independent organizations that collect waste from multiple producers for centralized processing. This model represents 35% of cases. A composting plant in Ecuador processes 15,000 tons of waste annually from 47 producers, generating 6,000 tons of compost sold at prices 30-40% lower than synthetic fertilizers.

Model C: Integrated Biorefineries. Facilities that implement multiple valorization routes through a cascade of processes. This model, present in 20% of cases, maximizes value extraction through sequential fractionation. One Spanish biorefinery processes olive waste through: extraction of hydroxytyrosol, enzymatic hydrolysis for fermentable sugars, fermentation for bioethanol, anaerobic digestion for biogas, and composting of the digestate. This processing achieves valorization rates exceeding 85%.

3.3. Economic Viability and Return on Investment

The projects analyzed show variable payback periods depending on scale and technological route. Small-scale composting projects (capacity 500-2,000 tons/year) have payback periods of 2.5-4.5 years with internal rates of return of 18-28%. Medium-scale anaerobic digestion plants (capacity 5,000-15,000 tons/year) show payback periods of 5-8 years and rates of 12-18%, improving with tariff incentives for renewable energy.

The extraction of bioactive compounds has the highest margins (61-150% over costs) but requires higher initial investments (USD 150,000-500,000 for pilot plants) and access to specialized markets. The cost-benefit analysis of four phenolic compound extraction projects indicates positive net present values, with benefit-cost ratios between 1.8-3.4 over a 10-year horizon.

3.4. Quantified environmental impacts

The cases studied document significant reductions:

Reduction of greenhouse gas emissions. Composting 1,000 tons of fruit and vegetable waste prevents emissions equivalent to 400-650 tons of CO_2eq annually compared to landfill disposal. Replacing synthetic fertilizers with compost reduces CO_2eq by 0.8-1.2 tons per ton of nitrogen replaced.

Conservation of water resources. The production of second generation bioethanol from bagasse consumes 60-70% less water than first-generation ethanol. The extraction of bioactive compounds using green technologies reduces the consumption of organic solvents by 75-90%.

Reduction of pollutant load. Processing olive mill effluents through anaerobic digestion reduces chemical oxygen demand by 85-95%, generating biogas with an energy potential of 250-400 m^3/ton of COD removed. Integrated systems reduce environmental management costs by 50-70%.

3.5. Barriers Identified for Scaling Up

The analysis identified five categories of recurring barriers:

Technological barriers. Limited access to appropriate technologies for small and medium-sized enterprises (SMEs), which represent 85% of the agribusiness sector in Latin America.

Technologies for extracting bioactive compounds and bioplastics require specialized equipment with investments between USD 200,000 and 2,000,000. Only 12% of the SMEs analyzed implement valorization processes beyond basic composting.

Economic and financial barriers. High initial costs, payback periods longer than SMEs' planning horizons (typically 2-3 years), and limited access to green financing. 68% of respondents identified capital availability as the main obstacle. Interest rates for agribusiness financing in Ecuador range from 9-14% annually.

Regulatory and institutional barriers. Fragmented regulatory frameworks that do not recognize waste-derived products (difficulties in obtaining health registration for organic fertilizers, lack of standards for bioplastics), complex bureaucratic procedures, and a lack of coordination between sectoral policies. The lack of specific tax incentives limits competitiveness compared to conventional alternatives.

Market barriers. Low willingness to pay premiums for sustainable products in local markets, information asymmetries regarding the properties and benefits of circular products, competition from subsidized products, and insufficient marketing channels. Only 23% of the bio-based products analyzed access premium markets. The marketing of compost faces competition from synthetic fertilizers with prices reduced by subsidies.

Cultural and training barriers. Resistance to organizational change, limited technical capabilities in bioprocess management and negative perceptions about the quality of waste-derived products. 54% of respondents reported internal resistance to modifying established processes. 71% of composting system operators lack specific training in controlling critical parameters, resulting in inconsistent product quality.

DISCUSSION

The results confirm the transformative potential of the circular economy for the agro-industrial sector, highlighting three dimensions of impact: business competitiveness, environmental sustainability, and territorial development (17).

4.1. Competitiveness and Productive Diversification

The valorization of agro-industrial waste constitutes a competitive differentiation strategy through three mechanisms.

First, the reduction of operating costs derived from lower final disposal expenses and partial substitution of external inputs. The cases document savings of 15-40% in fertilization costs by replacing agrochemicals with on-farm compost, and reductions of 30-60% in waste management costs.

Second, the creation of additional business lines that diversify portfolios and reduce vulnerability to fluctuations in primary markets. Fruit processing companies that incorporate the extraction of bioactive compounds report increases of 8-22% in total revenue, with higher margins (45-80%) than conventional products (15-25%). This diversification is strategic in sectors with high price volatility.

Third, access to premium market segments that value sustainability attributes. The analysis identified growing demand in European and North American markets for products with environmental certifications (18). Exporters who document circular practices through traceability access premiums of 10-35% in fair trade and organic markets.

Technological innovation is emerging as a critical determinant of competitiveness. Companies that invest in R&D for process optimization develop competitive advantages through patents and proprietary know-how. The development of appropriate technologies adapted to operational scales, local waste characteristics, and socioeconomic conditions represents an opportunity for research institutions.

4.2. Contribution to environmental sustainability objectives

The quantified environmental impacts validate the circular economy as an effective instrument for climate change mitigation, biodiversity conservation, and sustainable resource management. The magnitude of GHG emission reductions is 400-650 tons of CO_2eq avoided for every 1,000 tons of waste valued resources position circular management as a cost-effective mitigation alternative, with frequently negative abatement costs (generating simultaneous economic benefits) (19).

Water resource conservation is strategic in contexts of increasing water stress. Reductions in water consumption (60-70% in second-generation bioethanol) and nutrient recovery that prevents eutrophication generate quantifiable ecosystem benefits.

However, a holistic assessment requires life cycle analyses that consider potential trade-offs. Anaerobic digestion, while reducing methane emissions from uncontrolled decomposition, can generate emissions during operation. Bioplastics production can increase pressure on land use if it competes with food production. Comparative LCA studies are needed to substantiate environmental superiority over alternatives (20).

4.3. Territorial Development and Job Creation

The circular economy in agro-industry presents potential for the development of rural territories through three avenues (21).

First, the generation of direct employment in value-added activities. Estimates indicate the creation of 0.8–1.5 direct jobs for every 1,000 tons processed annually, multiplying by a factor of 2.5–3.5 when indirect jobs are included.

Second, the retention of added value in territories of origin through local waste processing. Cooperative value-added models in producing areas allow economic benefits to be distributed among small producers. Community composting experiences in Ecuador demonstrate increases of 12–18% in the net income of participating small farmers.

Third, strengthening the technical and organizational capacities of rural communities. Bioprocess management training programs generate human capital that transcends specific projects. 63% of participants in training programs reported applying their knowledge in other productive initiatives.

4.4. Role of Public Policies and Institutional Frameworks

Comparing cases between countries demonstrates the centrality of enabling institutional frameworks for scaling up. Countries with integrated waste management policies, tax incentives, sustainable public procurement, and concessional financing show higher adoption rates. Spain and Italy have favorable institutional ecosystems: regulatory frameworks that facilitate the recognition of waste-derived products, subsidies for investment in technologies, guaranteed tariffs for renewable biomass energy, and programs for green public procurement. These instruments reduce investment risks and accelerate payback periods.

Latin America shows fragmented frameworks. Isolated initiatives exist (biodigester programs in Colombia, green credit lines in Brazil) but lack systemic articulation. The absence of technical standards for organic fertilizers (only 4 of the 11 countries analyzed have specific regulations), bioplastics, and biofuels generates regulatory uncertainty that inhibits investment. Effective implementation requires integrated policy packages that address technological dimensions (support for R&D, technology transfer), economic dimensions (concessional financing, tax incentives) (22), regulatory dimensions (quality standards, expedited procedures), and informational dimensions (certifications, labeling, awareness campaigns).

4.5. Scalability and replicability of circular models

The analysis identified critical success factors:

- **Volume and stability of waste supply**. Successful projects ensure a constant supply through long-term contracts with multiple generators. Aggregating waste from small producers through cooperatives solves problems of scale and seasonality.

- **Technological adaptation to local contexts**. Uncritical transfer of technologies developed for different contexts is a frequent cause of failure. Robust, easy-to-operate, low-maintenance, appropriate technologies show greater sustainability in SMEs.

- **Articulation of value chains.** Successful projects establish links with bioproduct demanders, ensuring commercialization. Long-term supply contracts reduce commercial risks and facilitate financing.

- **Associative models and participatory governance.** Community valorization experiences show greater resilience when they incorporate inclusive governance mechanisms and equitable distribution of benefits. Models driven exclusively by external agents present higher abandonment rates.

4.6. Limitations of the Study and Future Directions

This research has limitations. The qualitative approach based on case studies, while allowing for a deep understanding of dynamics, limits statistical generalization. Quantitative studies with representative samples are needed to validate identified patterns. The availability of detailed economic data was heterogeneous, hindering rigorous comparisons of financial viability. Future research should employ standardized cost-benefit analysis and life cycle assessment methodologies.

The analysis focused on technical, economic, and environmental dimensions, insufficiently addressing sociocultural aspects that condition long-term sustainability (23). Ethnographic approaches would complement the findings.

Priority directions for future research include: longitudinal studies of circular projects, distributional impact analysis, assessment of systemic effects in territories with a high concentration of circular initiatives, development of decision support tools for selecting valorization routes, and research on innovative financing models.

CONCLUSIONS

The circular economy represents a viable and necessary strategy for the sustainable transformation of the agro-industrial sector (24).

The valorization of agro-industrial waste through diversified technological routes generates products with growing demand in specialized markets. Technical feasibility has been demonstrated in multiple geographical contexts and subsectors, with competitive conversion yields, product qualities, and environmental performance indicators. Scalability requires technological adaptation to local conditions, robust technical capacities, and access to appropriate financing.

The circular economy generates tangible economic benefits through reduced operating costs (15-60% in waste management and input procurement), revenue diversification (8-22% additional turnover), and access to premium markets with markups of 10-35%. Financial viability is positive in most cases, with payback periods of 2.5-8 years depending on the technology route and scale.

The environmental impacts are substantial and quantifiable. The valorization of organic waste avoids emissions of 400-650 tons of CO_2 equivalent for every 1,000 tons processed, reduces water consumption by 60-70% for second-generation processes, and decreases pollutant loads by 85-95%. These benefits generate positive externalities that, if internalized through appropriate economic instruments, would improve the competitiveness of circular projects.

The consolidation of the circular economy faces multidimensional barriers that require systemic interventions (25). Technological, economic-financial, regulatory-institutional, market, and cultural barriers cannot be resolved through isolated actions. Integrated public policy packages are required, including: development and transfer of appropriate technologies, concessional financing with investment guarantees, regulatory frameworks that recognize waste-derived products, differentiated tax incentives, green public procurement that generates assured demand, and sustained training and awareness programs. The articulation of actors—businesses, producers, institutions of research, governments, and civil society organizations—through collaborative platforms is a necessary condition to overcome fragmentation and build circular innovation ecosystems.

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