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"Only on Paper": A Multi-Level Stakeholder Analysis of Barriers to Sustainable Manufacturing in the Egyptian Food Industry

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Abstract

Sustainable manufacturing offers firms the chance to optimize resources, improve market access, enhance long-term competitiveness, and reduce the firm's environmental impact. However, implementation remains limited, especially in developing countries. This study investigates the barriers to sustainable manufacturing practices (SMP) in the Egyptian food industry and proposes strategies to accelerate adoption. Drawing on semi-structured interviews with 27 stakeholders and participants from manufacturing firms, we developed a multi-level framework to link macro-, meso-, and micro-level barriers. The study clarifies how barriers operate in practice and reinforce one another through contextual mechanisms that sustain resistance to SMP implementation. Beyond financial and technical constraints, the critical yet underexplored sources of resistance include institutional distrust, managerial mindsets, and socially embedded norms normalizing regulatory avoidance. This study contributes to research on sustainable manufacturing by stressing the need to consider institutional, behavioral, and socio-cultural conditions alongside corporate constraints to explain the persistent gaps in implementation in developing countries. It also provides a roadmap for coordinated stakeholder action to accelerate the transition toward sustainable manufacturing.

Keywords: sustainable manufacturing practices; barriers; multi-level analysis; developing countries; food industry

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1. Introduction

Manufacturing industries are pivotal to economic development, particularly in developing countries [1]. While manufacturing accounts for about 10–13% of gross domestic product (GDP) in developed economies, it exceeds 20% in developing nations [2]. Environmental challenges, including climate change, resource depletion, and pollution, intensify concerns about the sustainability of industrial practices. The largest contributor to CO_2 emissions, the industrial sector accounts for about 20% of global emissions [3] and 37% of final energy consumption [4]. These concerns have prompted growing calls to

adopt environmentally sound manufacturing practices to curb emissions, optimize resource use, and foster long-term ecological resilience.

Recently, sustainable manufacturing practices (SMP) have garnered significant attention from researchers and practitioners [3,5]. SMP seeks to reduce the ecological footprint of manufacturing while balancing economic, environmental, and social objectives, often necessitating strategic trade-offs [1]. This involves designing and managing all phases from product design and procurement to warehousing and retailing, in a manner that minimizes adverse impacts on both the environment and stakeholders, including consumers, employees, and communities [3,5].

Growing public awareness, stricter environmental regulations, and pressure from international trading partners are among the key drivers of SMP adoption [6,7]. Enhancing environmental performance can contribute to cost efficiency, foster innovation, strengthen brand reputation, and improve market competitiveness [1,5]. However, SMP adoption has progressed more slowly in developing countries than in developed ones, despite the potential benefits [3,5,6,8]. For example, developed countries exhibit higher adoption rates of ISO 14001 [9](environmental management systems) particularly in Europe and Japan. China stands as an exception, surpassing many developed nations in ISO certifications, whereas adoption remains considerably lower across most MENA (Middle East and North Africa) and African countries [10].

Although barriers to SMP implementation vary across contexts, most studies focus on sustainability practices in developed countries [3,6,11]. However, interest in emerging countries has grown due to their large populations, vast territories, and rapid economic growth [8]. Industrial manufacturers initially valued these markets for low-cost production, but now see them as strategic manufacturing and market expansion hubs [8].

Despite the rising integration of MENA countries in global supply chains and rising pressure to adopt environmentally responsible practices, this region is seldom studied. Addressing the gap, this study investigates the barriers to implementing SMP in Egypt, the most populous country in MENA [12] with one of the highest shares of manufacturing to GDP (15%) [2].

SMP varies across industries, requiring sector-specific approaches. This study focuses on food manufacturing, where high resource consumption, waste management challenges, and product perishability create unique barriers to sustainability. In Egypt, the food industry is a key driver of economic and social development, providing substantial job opportunities, and its strong export position contributes to foreign currency earnings [13]. Sustainable manufacturing depends on coordinating multiple actors, such as industry, government, and research institutions [14–16]. Yet little empirical research is unpacking the multi-level barriers that influence SMP adoption. Therefore, this study applies a multi-level (macro, meso, micro) analytical framework to (i) identify the key barriers to sustainable food manufacturing in Egypt, and (ii) develop strategies to promote its implementation.

The study contributes to both the literature and practice. First, to our knowledge, it is one of the first empirical studies to examine barriers to SMP in Egypt's food industry, addressing a critical gap in the literature. Its multi-level analytical framework explains how sustainability barriers emerge and interact across macro-, meso-, and micro-level contexts. Second, its stakeholder perspective incorporates insights from senior managers, business owners, NGO representatives, academics, and regulators, moving beyond the focal-company viewpoint that dominates other studies. From a practical standpoint, identifying sector-specific barriers enables stakeholders to allocate resources strategically and develop targeted strategies to scale up sustainable practices.

The rest of the paper is structured as follows. Section 2 reviews the literature. Section 3 details the methodology. Section 4 presents the findings. Section 5 discusses both

theoretical and practical implications, acknowledges research limitations, and offers recommendations for future studies.

2. Literature Review

2.1. Sustainable Manufacturing

There is no universally accepted definition of sustainable manufacturing [17]. The lack of consensus is largely attributed to diverse interpretations of the inherently multidimensional concept of "sustainability" [18]. Early efforts focused on "environmentally conscious manufacturing", entailing pollution prevention, waste minimization, design for the environment, and resource efficiency [3]. Subsequently, many new concepts further embed sustainability principles in manufacturing systems, such as industrial ecology, ecological footprint, cradle-to-cradle design, closed-loop system, and Rs strategy (e.g., reduction, remanufacturing, recycling, and reuse) [7].

In 2008, the US Department of Commerce proposed this definition: "The creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers, and are economically sound" [18]. Widely adopted, this definition stresses a balanced approach to sustainability that aligns manufacturing practices with both ecological responsibility and socio-economic goals.

From a life-cycle perspective, SMP can be categorized into four phases [1,5]. First, sustainable product design and development, also known as design for sustainability, integrates environmental, social, and economic considerations from the earliest design stages, where nearly 80% of a product's sustainability impacts are determined [19,20]. It addresses consumer needs holistically and sustainably using such tools as product life-cycle assessment and quality function deployment [19–21].

Second, sustainable manufacturing processes place sustainability at the core of production by conserving materials and energy, reducing emissions and waste, eliminating hazardous and toxic substances, and minimizing physical risk to employees [1]. Lean, agile manufacturing focused on value-stream optimization and waste elimination represents a basis for developing more effective, sustainable manufacturing strategies [22–24]. Advanced computer-aided methods can further optimize operations by integrating material, energy, and waste flows to identify process interactions and losses that can be repurposed into valuable inputs [25].

Third, sustainable supply chain management (SSCM) extends sustainability beyond a firm's own operations to both upstream and downstream activities associated with products, services, finances, and information flows from origin to end customer. This is critical because supply chains account for substantial resource use and emissions associated with consumer goods [26,27]. However, SSCM faces great challenges due to the interdependence of the supply chain actors. Complexity is intensified in global supply chains, where the actors are geographically dispersed [28].

Fourth, end-of-life practices (EoL), including reuse, recycling, and remanufacturing, aim to recover materials or components at the end of a product's life, thereby preserving the product's value beyond its initial use [29,30]. Incorporating EoL considerations into product design can help manufacturers reduce environmental impact by facilitating more sustainable post-use pathways [29].

2.2. Barriers to Sustainable Manufacturing

Many studies have examined barriers to SMP, showing that the challenges vary across regions, sectors, and institutional contexts (see Supplementary Materials, Table S1). In developing countries, these barriers are often deeply connected to economic, political,

institutional, and infrastructural conditions. Internally, firms often struggle with weak organizational and managerial capability, such as a lack of top management commitment, poor coordination, limited vision, and inadequate support from middle and lower managers [31,32] (see Supplementary Materials, Table S2). These barriers are reinforced by resistance to change and negative perceptions of sustainability, especially when financial pressure makes leaders reluctant to depart from traditional practices. Knowledge and skill barriers are also widespread because of inadequate educational and training systems [6,32]. Financial constraints are profound in developing economies, where limited access to funding, high capital costs, and uncertain short-term economic returns from sustainable practices are strong deterrents [32,33]. Technical and operational challenges, such as no standardized metrics, weak monitoring systems, and problems with supplier assessment, further impede progress [11,34].

External barriers such as weak institutional frameworks, inconsistent regulations, few government incentives, corruption, and poor infrastructure significantly constrain SMP efforts [6,11,33]. Market-related limits, including low consumer awareness, minimal investor pressure, and the economic vulnerability of communities, reduce the demand for green products and practices [32,34,35]. Fragmented supply chains and limited collaboration with research institutions hinder innovation and the diffusion of sustainable technology. These interconnected barriers highlight the need for integrated, locally informed strategies that align organizational development with policy, economic, and social reforms. Prioritizing the barriers with the greatest impact is essential to devising strategies that support SMP adoption in the Egyptian food industry.

2.3. Food Industry in Egypt

The food manufacturing sector is crucial to Egypt's economic growth and food security. In 2023, the Chamber of Food Industries had about 23,000 member companies operating in the formal economy [36], with investment totaling about EGP 500 billion. In 2024, the total value of Egypt's food-processing exports reached USD 6.1 billion for 15% of overall exports, thus making it the third-largest export sector [37]. The principal markets for Egyptian food products are the Arab countries and the European Union [38]. Major commodities are soft drink concentrates, flour and starch products, frozen strawberries and vegetables, juices, biscuits, and table olives [38].

Besides rising costs, Egypt's food industry faces major environmental challenges that threaten development goals. Water scarcity is critical, as Egypt has an average annual water deficit of 21 billion cubic meters [39,40]. Since food production is intrinsically connected to water through the food-water-energy nexus [41], shortages impede cultivation and processing. Egypt's energy system suffers from chronic load shedding because of the persistent mismatch between supply and demand. An outdated power grid hinders industrial productivity and compromises household stability [42]. Furthermore, its dependence on imported fossil fuels and limited investment in clean energy technology intensify these vulnerabilities [42]. In addition, land degradation and climate change are putting pressure on food production, making it lag behind the growth in the population's needs.

Clearly, Egypt must prioritize resource efficiency, material recovery, and expanded renewable energy. Robust sustainability policy is needed to integrate sustainable development principles into national strategy and tackle sector-specific barriers to implementation. Addressing this need, this study adopts a multi-level analytical framework to analyze the key barriers to SMP adoption and develop an actionable agenda to accelerate the transition to sustainable food processing in Egypt.

3. Research Methodology

3.1. Research Design

The study uses a qualitative, descriptive approach to examine participants' views on the drivers, barriers, and strategies for improving SMP adoption in the food industry. It provides a rich description of poorly understood phenomena while remaining close to the data and minimizing theoretical abstraction [43].

3.2. Data Collection

Data were collected in semi-structured interviews with diverse stakeholders to allow for consistency across interviews and provide the flexibility to adjust questions in response to emerging insights [44,45]. Supplementary Materials S1 presents the interview guide.

Data were collected in phases. Phase 1 (May–August 2025) interviewed experts, including sustainability consultants and academics, government officials, NGOs working on sustainability-related initiatives, and industry representatives. Phase 2 (February 2026) interviewed senior managers from food manufacturing companies to examine whether the barriers identified in Phase 1 were reflected in firms. The first author, who is Egyptian, conducted all interviews, either face-to-face or online. All sessions were recorded, except for one group, where detailed notes were taken.

Finding participants with relevant sustainability experience was challenging, so the authors relied on professional networks and purposive sampling to identify and capture the perspectives of various stakeholder groups across the food sector. Table 1 summarizes the interview inclusion criteria.

Table 1. Inclusion criteria for selecting interview participants.

Stakeholder Group	Inclusion Criteria
Senior managers (Food manufacturing factories)	- Mid-sized factory (50–250 employees) with sustainability practices - Located in different governorates to ensure regional diversity - Senior manager (e.g., operations, quality, sustainability) - Direct experience/involvement in the factory's sustainability transition
Experts (sustainability consultants, academics, government officials, NGO representatives)	- Five or more years' experience in environmental protection, social responsibility, industrial development, or food safety initiatives - Experience in the food manufacturing sector - Knowledge of sustainability policies, frameworks, assessment tools, or implementation practices relevant to manufacturing

In total, 27 participants represented various stakeholder groups in the food manufacturing sector. They included seven senior managers from three mid-sized factories in three governorates, and two industry-experienced participants from other firms. Supplementary Materials, Table S3, presents the characteristics of the three focal manufacturing companies. Interview sessions totaled 26, including two group interviews and two interviews with participant 13. To ensure confidentiality, participants' identities were anonymized (see Supplementary Materials, Table S4).

3.3. Data Analysis

All interviews were held and transcribed in Arabic by the first author. A certified translator translated the anonymized transcripts into English. The first author checked the translations against the transcripts to ensure meaning was preserved. After familiarizing ourselves with the data, we conducted a thematic analysis following Braun and Clarke's

approach [46] to identify recurring themes that reflect the participants' shared barriers and strategies for promoting SMP.

Our hybrid thematic approach [47] combined deductive and inductive coding, beginning with theory-informed codes derived from the relevant literature. The final set included more than 40 deductive codes structured in two dimensions: internal and external barriers to sustainable manufacturing [48]. Internal barriers were organized in meta-categories: organizational and managerial; attitudinal and behavioral; training and technical capability; and financial barriers. The external barriers were market; policy and regulatory; and government institutional. The framework was the basis for arranging the barriers across macro-, meso-, and micro-levels. Inductive coding allowed us to derive new concepts from the data, such as "corrupted certification bodies" and "SMEs dominance," aspects not previously discussed in the literature. We used Atlas.ti software (version 25) for coding and data management. The first author conducted the primary coding using the original Arabic transcripts.

Related codes were grouped into broader themes reflecting recurring data patterns (e.g., weak enforcement, weak R&D). Codes and themes were continually reviewed and refined, and labels assigned to each theme were modified to reflect their meanings. Analysis was an iterative process with continuous movement between data, codes, and themes. The second author reviewed the English material for emerging themes and interpretations. Both authors resolved any differences through discussion and by referring to the interview data. Supplementary Materials, Table S5 gives examples of the initial codes grouped in broader themes across the three levels of analysis. The authors' review of codes and themes and cross-stakeholder comparisons strengthen the credibility and reliability of the findings. Saturation was assessed in the transcription and preliminary coding stages of data collection. By the end of Phase 1, later interviews no longer generated substantively new themes. Phase 2 confirmed existing patterns and gave firm-level examples.

4. Results

4.1. Urgent Sustainability Challenges

First, we identified the urgent sustainability priorities requiring managerial attention in the Egyptian food manufacturing sector. Water mismanagement is the most pressing challenge since food processing is water-intensive, and much wastewater remains untreated. This is a major problem because high organic and microbial loads require costly treatment processes to meet regulatory standards for discharge into the sanitary sewer system. Due to increasing water scarcity in Egypt, disposing of wastewater without recovery or reuse is not a viable option.

Biowaste generation is a big concern. "Juice extraction yields about 50–55% of the fruit's weight, and the rest becomes solid biowaste. On average, every 100 tons of raw material generates about 50 tons of solid residue" (Interviewee 13). Largely biogenic waste poses a lower ecological risk than the waste of other industrial sectors. Although it can be used in animal feed or for extracting value-added products, valorization faces major challenges for transport, preservation, and storage. High microbial activity requires rapid cooling, which increases operational costs, so many small enterprises rely on contractors whose role is mainly disposal rather than recovery.

The consumption and high carbon footprint of energy are significant challenges. The sector relies on energy-intensive production and logistics processes, exacerbated by the ongoing dependence on conventional energy sources and limited adoption of renewable alternatives.

The critical challenge in the social dimension is the widespread use of informal labor, which severely limits effective oversight and enforcement of labor standards. One participant estimated, "Across the agro-food manufacturing supply chain […] some 30%

[employees] are formally contracted and insured, with clear employment records, while the remaining 70% are not officially registered" (Interviewee 16). This high level of informality makes employment conditions largely untraceable and leaves workers' rights inadequately protected.

Gender inequality is rife: men dominate managerial positions while women are mostly confined to low-skilled, low-paid jobs. Substantial gender-pay gaps persist, sometimes reaching extreme levels, with women earning less than half of men's salaries for comparable work. Working environments often lack basic gender-appropriate facilities such as restrooms for women, which may expose women to harassment. Limited access to support services such as childcare and safe transport, especially in rural areas, constrains the participation and career advancement of women, reinforcing gender-based disparities across the sector.

4.2. Drivers for Sustainable Food Manufacturing

Most experts asserted that Egyptian manufacturers show little concern for environmental or societal issues. Export market demand primarily drives SMP adoption. One participant estimated, "In about 95% of cases, decision-makers pursue sustainability practices primarily to meet mandatory requirements, particularly for export markets, rather than by choice. Only a small minority are genuinely aware of the importance and potential benefits of sustainability" (Interviewee 4).

Sustainability serves as a branding tool to target the wealthy elite and young generations, such as Gen Z and Gen Alpha, who tend to be concerned about the environment and healthy living. In addition, certification schemes (e.g., ISO 22000 and ISO 14001) can help companies restore their reputation, particularly following incidents such as food safety scandals.

Economic drivers, like reducing costs through improved efficiency and optimizing resources, play a significant role. One expert mentioned a factory owner who had invested in solar energy. The owner had told him, "I benefit lots from solar panels. Now I supply part of my surplus to the grid, which saves me a great deal […] especially since power cuts occur frequently. I solve this by having batteries available at all times" (Interviewee 11).

Regulatory drivers influence SMP adoption, especially when policy is a response to a specific crisis. For example, one national initiative to use more food and agro-processing waste in animal feed was introduced to address the feed shortages caused by the limited availability of raw materials and rising exchange rates driving up import prices.

Other drivers are religious and ethical concerns. Some firms motivated by faith and ethical values are socially responsible, especially in supporting workers. "Some companies are not even aware that what they are doing constitutes an aspect of sustainability. They often call it simply 'doing good for God.' While these acts are indeed charitable, they also align with sustainability principles" (Interviewee 12). One factory manager indicated, "We participated in an initiative to let students train in our factory. We did it for God, but other factories might not do the same" (Interviewee 27). Finally, concerns about contamination and product quality, stemming from unsafe production practices such as the improper use of diesel-powered equipment, create operational pressures for firms to adopt clean sustainable technology.

4.3. Barriers to SMP

We categorized the barriers to SMP in three interrelated levels: macro, meso, and micro (see Figure 1). This classification emphasizes the multi-level nature of transition to sustainable manufacturing because it shows how barriers operate across individual, organizational, sectoral, and institutional levels. The core barriers were broadly consistent

across stakeholder groups, with minor differences in emphasis and prioritization. The barriers are presented below according to recurring emphasis across stakeholder groups.

4.3.1. Macro-Level Environment

Macro-level barriers arise in the broader external context, shaped by national, systemic factors that affect the ability and willingness of food manufacturing firms to adopt SMP.

First, weak government control and inspection is the most critical barrier across the environmental, social, and food safety aspects of manufacturing. Several experts emphasized that the enforcement of formal regulations is weak, inconsistent, and often selective. One interviewee noted, laws often exist "only on paper, and they are not enforced or enforced arbitrarily," making compliance optional or symbolic. Interviewees said that inspections were largely reactive rather than proactive or regular, usually triggered by complaints, and the response depended on the source of the complaint. "If a complaint comes from [the police], an inspection is usually conducted within two days. Whereas complaints submitted by ordinary citizens often take significantly longer to be addressed" (Interviewee 17).

Weak enforcement contributes to the spread of informal, unlicensed "below stairs" factories that supply the market with low-quality products, creating major challenges for compliant firms. One CEO mentioned the impact of a neighboring, unregulated poultry waste processing facility: "The smell is so bad that our workers sometimes have difficulty breathing." Such conditions also create reputational challenges as visiting clients "often notice the smell, and we have to explain that it does not come from our operation but from outside" (Interviewee 21). This lack of oversight extends to the wider supply chain, including distribution, logistics, retail, and waste management. For example, hotels and restaurants sell leftover food in local markets as a form of recycling. However, in the absence of adequate quality and health controls, such practices may reflect improper waste handling rather than genuine efforts in sustainability.

Several factors contribute to inadequate control and accountability, such as weak ethical leadership in inspection bodies, corruption, and personal connections between facility owners and officials used to resolve violations informally. Enforcement capacity is further constrained by severe shortages of inspectors, low wages, inadequate training, limited logistical resources, and weak evidence-collection systems.

These conditions reduce the frequency and reach of field inspections, especially in remote areas, and increase the risk of informal payments. "Inspectors think that they should not bear work-related expenses, like paying for a mobile data package if the job does not provide one or using their own phone for photo or video evidence [...] In fact, this is a reasonable position given their limited salary" (Interviewee 17). Another participant added, "During inspections, factories might offer an informal payment [a bribe] in exchange for minimal fines or not recording the violation at all. Given their circumstances, the inspectors will definitely agree" (Interviewee 1).

Participants also focused on the challenges facing the National Food Safety Authority (NFSA). Established in 2017 to consolidate food safety oversight across more than 17 fragmented regulatory bodies, the transfer of inspection responsibility is still incomplete, maintaining uneven, fragmented enforcement. Temporary contracts and an unclear organizational structure also weaken staff retention, professional development, and institutional knowledge. The participants think that the NFSA focuses mostly on export-oriented companies, where the regulatory pressure is greater.

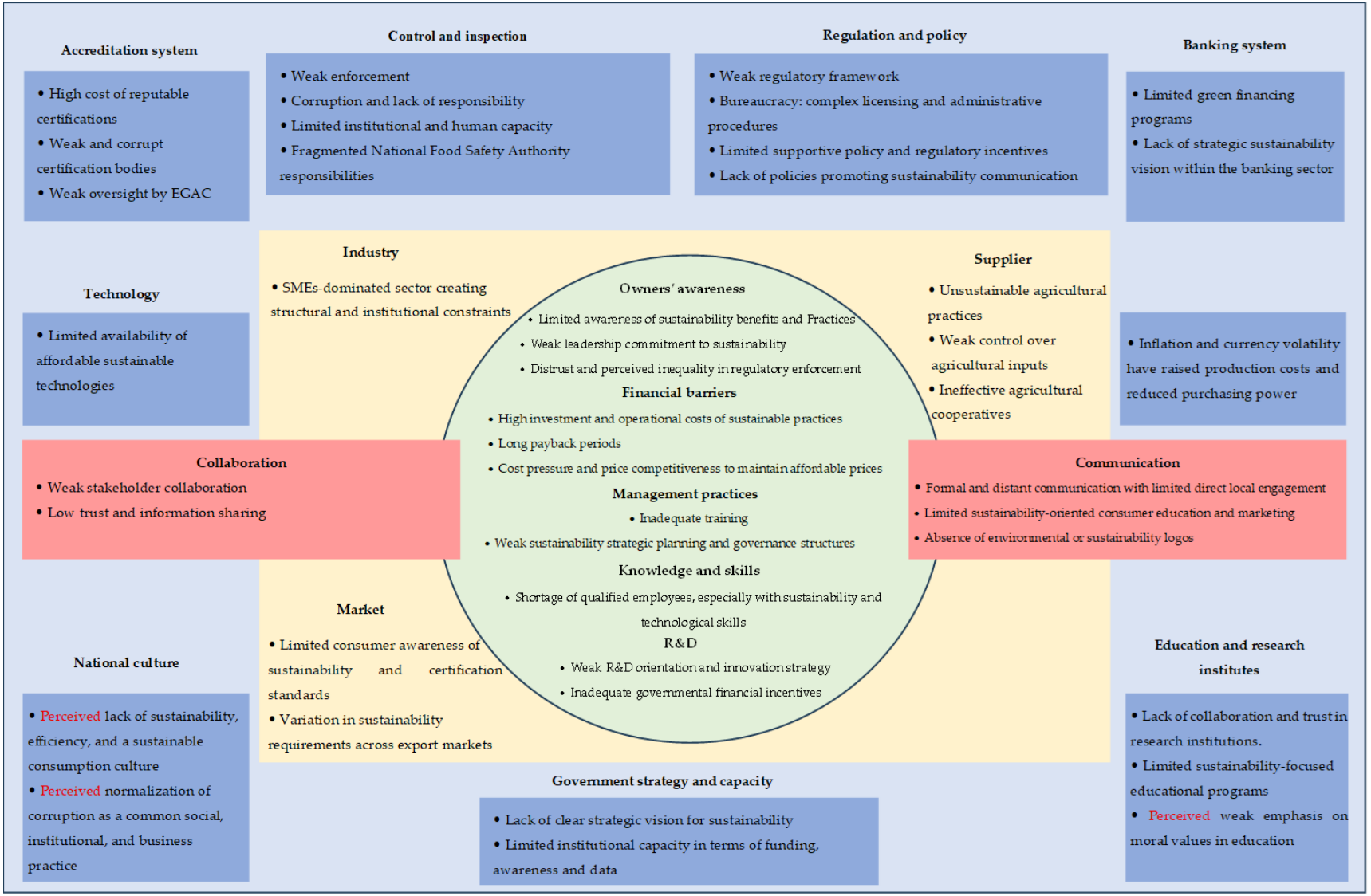


Figure 1. Multi-level framework of barriers to SMP in the Egyptian food industry.

Second, government regulations and policies are a major barrier. While many participants acknowledged that current regulations could support sustainable manufacturing, they identified several weaknesses in policy design that undermine a firm's willingness to comply. Participants cited legal loopholes, weak penalties, and inadequate transparency in disclosing the names of non-compliant factories to the public, all of which reduce regulatory effectiveness. Conflicts among enforcement authorities were also reported. Even when facilities are closed due to violations, "multiple authorities are involved. For example, the local district authority may have the power to reopen it. You can override the closure depending on where your personal connections and relationships are" (Interviewee 4).

Recent regulations issued by the Ministry of Industry were criticized for eliminating random inspections, replacing them with scheduled collective inspections, and restricting the authority to shut non-compliant factories without high-level approval. Participants argued that these changes "almost dismantle environmental compliance under the banner of accelerating industrial development" (Interviewee 17). "If factories know the inspection dates in advance, they can temporarily adjust operations before returning to their old practices" (Interviewee 4).

Participants viewed supportive policies and incentives as inadequate. They found government support largely symbolic and often limited to events rather than substantive measures such as tax exemptions, reduced customs duties, or financial incentives for sustainable infrastructure. The complicated licensing process is another burden that discourages SMP implementation. For example, "installing solar panels requires many government approvals because part of the generated electricity is connected to the national grid. Managers say, 'I keep going back and forth from one office to another just to get approval,' so they end up maintaining existing practices" (Interviewee 1). No policies encourage firms to communicate sustainability efforts to consumers, leaving many initiatives internal or compliance-driven.

Third, limited funding in the domestic banking system restricts a firm's ability to invest in SMP. Participants said that limited availability and scope of local green financing programs lead to strong reliance on international funding, such as from the European Bank for Reconstruction and Development. In contrast, engagement from local development institutions, including the Micro, Small, and Medium Enterprise Development Agency, was perceived as weak. Participants emphasized the lack of a sustainability vision to guide green financing policies in the banking sector. "Funding is available, but there is no clear strategic vision" (Interviewee 17).

Fourth, the certification and accreditation system is an important barrier. Certifications such as ISO 14001, ISO 22000, and ISO 45001 are vital to demonstrate compliance with environmental, social, and food safety standards, especially for export-oriented firms. Recent currency devaluation has substantially increased the cost of certification by reputable international bodies, pushing many firms, especially SMEs, to cheaper providers that apply less rigorous auditing. "Sometimes, providers act as 'printers', printing certificates […] without even doing an audit in some cases" (Interviewee 4).

Participants attributed the prevalence of corrupt certification providers to limited oversight by the Egyptian Accreditation Council (EGAC), which relies primarily on documentation-based reviews rather than performance assessment. Conflicts of interest may occur if the certification firm provides consultancy services and issues certificates simultaneously. "If the person who trains and implements, and his colleague in the same company is in charge of granting the certificate, so is it reasonable to expect them to fail themselves? Of course not." (Interviewee 3).

Fifth, participants viewed unstable economic conditions, especially high inflation and currency devaluation, as a significant barrier. Such conditions have sharply increased

production costs, pushing firms to prioritize control and short-term survival over investing in sustainability. Constant inflation has reduced consumers' purchasing power and increased price sensitivity, thereby limiting the demand for sustainable products.

Sixth, the limited availability of affordable sustainable technology and specialist technical support constrains SMP adoption, particularly for SMEs. Many sustainability-related technologies, such as sensors and solar energy systems, are not made locally in Egypt. Currency devaluation has increased the cost of importing technology substantially, leading many firms to rely on cheap, often outdated alternatives. "We launched a biogas project with an independent engineer, which helped us reduce energy costs by some 10%. But after five years, we stopped the project because of the lack of companies providing maintenance for the biogas digesters" (Interviewee 23).

Seventh, weak engagement between academia and industry is seen as an obstacle to addressing practical challenges and developing affordable solutions. "Industry practitioners may believe that academics cannot solve their practical problems, while simultaneously demanding rapid solutions" (Interviewee 3). Existing collaboration remains superficial, such as taking part in one-off student competitions, rather than sustained research-industry partnerships.

Interviewees attributed weak engagement to university bureaucracy, the limited industry experience of academics, the conservative mindset of university leaders who prioritize academic routines over applied research and external engagement, and a mismatch between short-term industry needs and longer research timelines. The lack of sustainability-oriented educational programs contributes to skill shortages in the sector, particularly in applied and technical areas. A couple of interviewees viewed the reduced emphasis on moral values in education as potentially contributing to the perceived normalization of unethical practices. "In the past, education emphasized moral upbringing before academic instruction, instilling values such as integrity, honesty, and respect. But this doesn't exist in education anymore" (Interviewee 20).

Eighth, broader cultural factors are seen as barriers to SMP adoption. Participants cited weak societal values in support of sustainability, including respect for nature, concern about efficiency and waste, and civic engagement. Some participants described an overconsumption culture, with conspicuous consumption used to display wealth and status, undermining sustainability-oriented behavior. "Unfortunately, we don't have a culture of responsible consumption. We are accustomed to […] buying food in large quantities. By the end of the week, about 25–30% of it is inevitably thrown away" (Interviewee 13).

Several interviewees perceived the normalization of corruption, common in social, institutional, and business practices, as a major constraint. A senior official in the Ministry of Agriculture said, "The country has reached a point where bribery has become one of the elements of management."

Participants attributed many of the macro-level barriers to sustainable manufacturing to the absence of a comprehensive government strategy. They emphasized the lack of a coherent sustainability vision, noting that economic growth continues to dominate policy priorities, often at the expense of environmental and social considerations.

Weak institutional capacity, particularly in funding, data availability, and awareness of sustainability, limits effective collaboration among NGOs, governmental bodies, and research institutions. "Implementing sector-wide initiatives like waste recycling would require extensive data collection and coordination across thousands of firms. In turn, this would need dedicated funding and institutional support that are currently lacking" (Interviewee 13).

4.3.2. Meso-Level Environment

Meso-level barriers operate at the market and sectoral levels, influencing firms' adoption of SMP through limited consumer pressure, supplier-related constraints, and weak collaboration across the food industry.

First, the structure of the food manufacturing sector is a key barrier. Participants estimated that about 85% of companies in the sector are SMEs with little financial, technological, and managerial capability. This makes the sector vulnerable to economic shocks and leads firms to make sustainability a low priority or "just the responsibility of big corporations" (Interviewee 12). Participants stressed that this perception is problematic as large firms are already subject to strict audits, while "the real challenge lies with SMEs, where compliance pressure is weaker and unethical practices are more prevalent" (Interviewee 3).

Location plays an important role in the adoption of sustainability. Firms in industrial zones benefit from access to infrastructure that facilitates compliance, while many SMEs operate in informal or unplanned locations, often in "the residential buildings or agricultural areas that don't have adequate infrastructure" (Interviewee 4).

Second, market-related factors were widely identified as barriers, especially low consumer awareness of environmental issues, food safety, and certification standards. Under the prevailing economic pressure, consumers are "primarily price-oriented, prioritizing cheaper options over quality or environmental considerations" (Interviewee 13).

Participants noted that consumers now find food safety risks normal. One interviewee contrasted Egypt with other Arab countries, explaining that in countries with higher food safety awareness, closing a restaurant or factory might discourage customers from returning. In Egypt, however, "when a facility is closed, once it reopens, customers will queue as if nothing had happened" (Interviewee 4). Limited understanding of certification standards further weakens consumer pressure, as the public may read terms like "ISO" without understanding the differences in certification credibility. As a result, consumer pressure on unsustainable firms is weak. However, participants observed early signs of change, with younger generations and more affluent consumer segments showing a growing awareness of sustainability issues. Export market dynamics also vary, as import markets place different levels of emphasis on certification credibility. Therefore, SMEs often target African markets, where sustainability compliance requirements are less stringent than in European markets.

Third, several supplier-related practices affect a firm's ability to adopt SMP. Unsustainable agricultural practices are widespread among suppliers, including excessive pesticide use, weak adherence to organic standards, and inefficient water and fertilizer management, often due to the lack of advisory support. "They don't do soil analysis to determine fertilizer requirements, or water analysis, resulting in excessive use of water and pesticides" (Interviewee 18). Such practices increase environmental risks, compromise product quality, and reduce the ability to meet sustainability and certification requirements. One CEO estimated, "In agro-processing, pesticide residues represent a major challenge, which significantly limits export potential; exports could be 10 times higher if this issue were addressed" (Interviewee 21).

Participants indicated that many agrochemicals on the market are either counterfeit or of poor quality due to weak oversight and the diminishing role of agricultural cooperatives in raising awareness, supplying quality input, and marketing support. "Used containers of reputable fertilizer companies are sometimes refilled and resold as genuine […]. The cooperatives used to provide quality input at a reasonable price and marketed crops on behalf of farmers […]. Unfortunately, they no longer perform this role" (Interviewee 2).

Fourth, communication gaps are another barrier to SMP adoption. Current stakeholder communication channels are formal and distant, relying mainly on websites,

emails, and workshops, with limited local or on-the-spot engagement. This reduces participation, particularly among firms located in distant governorates that are often unwilling or unable to attend events organized centrally in Cairo. Although some improvements have been made, such as enhancements to official websites, these measures remain insufficient in practice. "A factory in places like Beni Suef or Minya is unlikely to consult the Ministry of Environment's website […]. What we need is more on-the-ground guidance" (Interviewee 17).

Participants noted that companies engage minimally in sustainability-oriented consumer education and marketing, relying on traditional marketing practices, reflecting the perception that environmental concern is confined to higher-income consumer segments. "Companies target the largest segment of society, believing consumers are mainly concerned with price, then quality, and only a small segment is interested in sustainability-related issues […]. If legislation doesn't encourage companies to play a role in raising consumer awareness, they will never do so" (Interviewee 13). The lack of widely recognized sustainability labels further limits firms' ability to communicate sustainability efforts effectively.

Finally, lack of collaboration among stakeholders is a major meso-level barrier. Participants described the food sector as fragmented, with multiple overlapping authorities holding responsibility but with limited data sharing or coordination. "The main problem is the isolation in silos. More than one authority has jurisdiction over certain issues in the food sector, so each [silo] has its own data, and there is no connection between them" (Interviewee 10). This weak collaboration is reinforced by limited trust and poor information sharing among companies, government bodies, research institutions, NGOs, and supply chain actors. Firms were described as lacking trust in government bodies, due to concerns about regulatory scrutiny and potentially negative consequences. "Companies are wary of attracting government attention […]. They prefer not to be visible, and choose to stay low-profile and operate quietly" (Interviewee 11).

4.3.3. Micro-Level Environment

Micro-level barriers relate mainly to the attitudes of owners and managers, organizational culture, resource availability, and employee skills. Although micro-level barriers operate at the firm level, they often interact with external conditions to shape the company's strategy.

First, participants considered owners' limited grasp of the potential of sustainability as a critical micro-level barrier. They emphasized that many owners do not understand the financial and operational gains of investment in sustainability, such as cost savings, efficiency gains, and better market access. "Owners do not have awareness of the importance of sustainability or how it could benefit them" (Interviewee 7). This lack of awareness is pronounced among older, rural SME owners with lower levels of education and literacy.

Interviewees highlighted the ignorance of affordable practices, leading some firms to view sustainability as costly, despite the availability of low-cost measures. Due to these knowledge gaps, some firms, often driven by religious or ethical motives, engage in responsible practices without realizing they are sustainable, leading to informal, unstructured implementation.

Participants viewed weak management commitment and low priority for sustainability strategy as crucial factors. SMP adoption was described as primarily compliance-driven, particularly regarding export requirements or subsidies, leading to minimal, symbolic implementation. Distrust in the enforcement of regulations and the perception of unequal treatment further foster regulatory avoidance and reliance on personal networks to navigate administrative and compliance-related procedures. "Small firms know that

the major players have connections to influential officials who facilitate things for them. They therefore think, 'The authorities will come after me. I'm the small and vulnerable one'. They begin looking for ways to get around the system as well. There must be equality and respect for everyone. Only then will individuals feel obliged to comply and won't resent doing what they have to do" (Interviewee 20).

Second, financial and cost-related constraints were widely regarded as significant. High capital and operational costs, such as those associated with installing solar panels or wastewater treatment, combined with long payback periods and limited access to green financing, strongly deter firms from investing in sustainability. Economic instability and inflation intensify cost pressures and price competition, pushing firms to prioritize short-term affordability over sustainability investments. "The cost of constructing water treatment units is not the main problem. The real issue is monthly operational costs. Some companies establish treatment plants only as a façade, just for show" (Interviewee 13).

Third, the shortage of skilled employees, particularly those with green and technical competencies, constitutes another barrier. Large companies tend to absorb most of the skilled labor, leaving SMEs to rely on low-cost workers with little formal education, which constrains their ability to understand and comply with requirements. "They do not have awareness of basic hygiene practices, like the need to sanitize hands and feet […] and not enter production areas straight from the street before handling products that affect human health and safety" (Interviewee 13). This is exacerbated by high labor turnover, as workers often move between factories in search of better wages or conditions, making companies reluctant to invest in employee training.

Fourth, participants mentioned organizational and managerial barriers, such as poor training that translates into weak governance. Training evaluation practices were criticized for focusing on participant satisfaction rather than learning outcomes. Particularly in SMEs, the absence of formal sustainability strategy, plans, and dedicated organizational units hinders effective implementation. "Some firms say, 'We started, but everything stalled.' This is because they lack an internal governance structure to enable transition" (Interviewee 12).

Fifth, interviewees linked the scant attention paid to innovation to the low SMP adoption. Firms' R&D focuses on product improvement instead of developing manufacturing processes and innovation capability. "We're not technology producers. Developing technology requires experiments, trial and error […]. Business owners often ask, 'How much will I make tomorrow?' […] Firms prefer to stick to traditional practices. There is no strong culture of investors financing research and development" (Interviewee 1). Participants attributed this weakness to risk aversion, limited recognition of the strategic value of research, a short-term profit orientation, and a lack of an R&D investment mindset, both within firms and in partnerships with research institutions. Participants highlighted the lack of governmental financial incentives to encourage companies to invest in R&D.

4.4. Suggestions to Promote SMP Adoption

Experts made several recommendations for managers, policymakers, and industry associations to advance sustainable food manufacturing practices. They stressed that SMP adoption requires coordinated multi-stakeholder action rather than isolated initiatives. Their overlapping recommendations are grouped in broad strategic areas aligned with the identified barriers. Table 2 (below) summarizes the key strategies, and Supplementary Materials, Table S6, provides further details.

Table 2. Actionable strategies for promoting sustainable food manufacturing practices.

Strategic Area	Key Actions	Barriers Addressed	Primary Actors
Inspection, accountability, NFSA capacity	Increase the number and capabilities of inspectors; adopt proactive, random inspection mechanisms; provide adequate logistical and digital resources; strengthen anti-corruption controls; establish centralized digital databases for inspection data; improve NFSA governance; implement integrated traceability systems that link certified suppliers; expand NFSA's inspection scope across the entire food supply chain; establish feedback mechanisms, such as customer complaint systems and public reporting tools	Weak enforcement; limited inspection capacity; corruption; weak institutional coordination; NFSA fragmentation	NFSA; environmental and regulatory authorities;
Regulations, enforcement and incentives	Develop clear, enforceable, and transparent regulations; close legal loopholes; coordinate enforcement across agencies; apply meaningful penalties with substantial financial and legal consequences; introduce sustainability incentives such as tax reductions, subsidies, and recognition schemes; simplify licensing and registration procedures for SMEs and unlicensed factories; support for start-ups offering sustainability-related services and products	Regulatory ambiguity and loopholes; weak penalties; limited incentives; complex licensing	Regulatory and industrial authorities
Green finance and investment support	Develop a national green finance framework; expand low- or zero-interest loans for sustainable industrial projects; strengthen the role of local development institutions; and build partnerships with international development partners to support SMEs	Limited access to green finance; high investment costs; SME financial constraints	Financial institutions; international development institutions; policymakers
Certification, education, and technology	Implement performance-based evaluation and regular rating of certification bodies; conduct random audits; penalize malpractice; expand sustainability-focused education and technical training; localize clean technologies and strengthen technology transfer mechanisms	Weak certification credibility; gaps in skills and training; limited access to sustainable technologies	Regulatory and accreditation bodies; certification bodies; educational and training institutions
R&D, infrastructure, and innovation	Strengthen industry–university collaboration; provide financial incentives for R&D investment; support start-ups that commercialize sustainable technologies; develop green industrial zones and centralized waste-collection hubs	Weak R&D orientation; limited industry–university collaboration; infrastructure gaps	Universities and research institutions; firms; industry associations; industrial authorities
Cultural awareness of sustainability	Implement national campaigns on food safety, waste reduction, certification standards, anti-corruption, and environmental sustainability; reframe sustainability for business owners as a source of efficiency, savings, and competitiveness rather than a cost; improve awareness of the roles of national and international agencies; link financial incentives to participation in sustainability training and awareness programs	Low awareness of sustainability among managers; weak consumer awareness	Government agencies; industry associations; NGOs; educational institutions
Communication and consumer engagement	Promote direct field engagement between regulatory agencies and firms; introduce standardized sustainability labels or logos; and encourage firms to use sustainability marketing for differentiation	Weak communication; low awareness of and demand for sustainability among consumers	Regulatory authorities; industry associations; firms
Collaboration and supply	Establish structured platforms that connect government, industry, agriculture, NGOs, research institutions, and supply chain actors; promote peer learning	Weak stakeholder collaboration; fragmented supply chains	Industry associations; research institutions; supply chain actors

chain coordination	among business owners; reinforce agricultural cooperatives; and support collective purchasing initiatives for SMEs		
Sustainability capability at the firm level	Encourage firms to develop sustainability plans with measurable goals; invest in training across organizational levels; implement efficiency-driven systems such as data collection and performance monitoring; adopt clean technologies; and build a culture of continuous improvement	Weak sustainability governance; skills gaps; limited monitoring capability; short-term orientation	Firm owners and senior managers

5. Discussion

This study identified barriers to SMP in Egypt's food industry and proposed strategies to overcome them. It contributes to the literature on sustainable manufacturing by presenting a structured multi-level framework that integrates diverse stakeholder perspectives across macro-, meso-, and micro-levels. The findings show that SMP transition is shaped by interactions among institutional, sectoral, organizational, and individual factors. Incorporating behavioral and socio-cultural dimensions, including managerial mindsets and prevailing cultural norms, the framework extends current research on sustainable manufacturing in the context of a developing country.

The findings highlight the urgent social and environmental challenges facing Egypt's food industry, including high water consumption and waste, limited recycling of biowaste, and widespread reliance on informal labor. Identifying these pressures clarifies the sustainability-related priorities confronting the sector that scholars need to address. Consistent with prior research [49,50], market, economic, and regulatory factors emerged as key drivers of SMP. However, the study shows that religious and ethical motives also shape sustainability behavior, which means that research into making the transition to sustainable manufacturing in developing countries needs to consider contextual social and cultural drivers. While conceptual literature links Islamic teachings to responsible organizational behavior [51,52], there are few empirical studies that look at how corporate leaders' religious motives evolve into sustainability practice.

At the macro level, consistent with prior literature [35,53,54], weak regulations and ineffective enforcement emerged as prominent barriers to SMP. Similarly to previous research, the findings distinguish between the existence and actual enforcement of regulations [6,54]. However, this study extends earlier work by examining the underlying mechanisms sustaining weak enforcement, such as staff shortages, low wages, resource constraints, and corruption. Although bureaucracy and corruption are well-documented in development and management research [55,56], the implications for SMP implementation receive comparatively little attention, with only limited evidence coming from the MENA region [6].

Our findings reinforce prior evidence that limited supportive policies, weak financial incentives, and restricted access to green financing constitute major barriers to the adoption of sustainability [11,34,48]. We found that macro-economic instability, particularly inflation and currency volatility, intensifies constraints by increasing production costs and reducing a firm's ability to invest in sustainability. While many developing countries face similar challenges [57], the sustainable manufacturing implementation literature rarely treats economic conditions as barriers, with a few exceptions [6].

Another macro-level contribution concerns certification credibility. The literature has recently begun to examine how certification bodies influence the implementation of sustainability practices. According to Battisti et al. (2025), credible third-party certification reduces information asymmetry, whereas weak certification standards may legitimize greenwashing rather than prevent it [58]. This study extends this debate by showing how

high certification costs, weak oversight, conflicts of interest, and corruption undermine the credibility of sustainability standards in practice.

Consistent with earlier studies, the limited availability of affordable sustainable technologies [11,32,53] and weak collaboration between industry and research institutions [59] were also identified as persistent constraints. In addition, the findings reveal that the weak emphasis on moral and ethical values in education constitutes overlooked barriers to adoption. Scholars emphasize the need for moral and ethical education to drive responsible, ethical behavior, arguing that sustainability is a question of values [60,61], but there is little empirical evidence linking moral and ethical education to SMP implementation in the context of developing countries.

The findings highlight the role of the broader socio-cultural context as a barrier to SMP adoption. Prior research has focused on organizational culture in firms [53,62], leaving the influence of broader national cultural patterns less examined, especially in developing countries. A growing body of cross-country work links national culture to sustainability engagement, often drawing on Hofstede's cultural framework [63–65]. However, few studies examine how socially embedded behaviors, such as the perceived normalization of corruption, affect sustainable manufacturing implementation in developing economies. The findings underscore this gap. Cultural elements that resonate with sustainability principles are underrepresented in the Egyptian business environment. Framing sustainability practices through local religious values may enhance employee acceptance and engagement with the initiatives [66].

Finally, the findings point to the lack of a coherent national sustainability strategy, a macro-level barrier. Current studies emphasize that sustainability transition depends on the state-led alignment of regulatory frameworks, industrial policy, and long-term investment priority [67,68]. Comparative, longitudinal studies may deepen understanding of how policy fragmentation influences the coherent transition to sustainable manufacturing over time.

At the meso level, the findings confirm previous research showing that the lack of customer pressure [32,48], inadequate infrastructure [31,54], and unsustainable supplier practices [33,69] constrain SMP adoption. However, this study found that the structure of the food industry reinforces the barriers. The majority of SMEs operating informally or in poorly serviced locations have limited access to infrastructure, finance, technology, and compliance capability. The findings also show that weak collaboration, low trust, and little information sharing between firms, government bodies, and research institutions fragment sustainability efforts. The decline of agricultural cooperatives further weakens coordination across the food supply chain. Following the 1952 Revolution in Egypt, state leadership expanded agricultural cooperatives. However, from the mid-1970s onward, as Egypt moved toward a more open economy, many of the cooperatives' functions were reduced or transferred to other public or private actors. The cooperatives were not turned into autonomous, farmer-led organizations [70]. This suggests that market liberalization, when not accompanied by effective institutional reform, can create institutional voids that weaken coordination among farmers, manufacturers, and the state. This finding extends research on sustainable manufacturing by showing that capable intermediary institutions are vital in coordinating the transition in fragmented agricultural systems.

In contrast to prior research, the findings highlight communication-related barriers as an important meso-level constraint. Ineffective stakeholder communication, limited sustainability-oriented consumer education, and the absence of nationally recognized sustainability labels reduce the visibility of sustainability efforts, weakening public engagement. The finding supports studies that emphasize the role of corporate communication in achieving goals and advancing societal transition toward sustainability [71,72]. When communication is ineffective, sustainability is fragmented, suggesting that research into SMP

implementation must account not only for regulatory and market structures but also for effective communication systems that enable coordination and stakeholder engagement.

At the micro level, the findings confirm that low awareness of benefits [34,53] and weak management commitment [31,32] are central barriers to SMP. Financial constraints [11,33], inadequate training, shortage of expertise [6,31,32], and weak R&D investment [53,59] were also identified as barriers. However, this study extends current research by showing that resource-based barriers are also cognitive and behavioral barriers, shaped by owners' orientation to short-term profit, their limited recognition of the strategic value of research, risk aversion, distrust in regulatory institutions, and perception of unequal enforcement of regulations.

These findings shift the focus beyond a purely resource-based view of sustainability adoption to the behavioral and institutional foundations of corporate decision-making. Behavioral theory suggests that sustainability adoption is not only constrained by the availability of resources but is also rooted in managerial perceptions, temporal orientation, and mental models [73,74]. Accordingly, risk aversion and distrust in regulatory institutions may affect decision-making, encouraging avoidance rather than engagement with initiatives. Thus, research into sustainable manufacturing implementation needs to integrate behavioral and institutional logics to explain why firms in developing economies may resist adopting sustainability.

These results show how barriers interact with and reinforce one another across levels, maintaining persistent resistance to implementing sustainable manufacturing. For example, macro-economic instability and limited green funding both exacerbate the financial problems of firms and lead to a greater short-term orientation among managers. Weak regulatory enforcement fosters institutional distrust, a sense of inequality, and avoidance of rules. Meso-level barriers such as poor infrastructure and lack of collaboration across the food supply chain hamper sustainable capabilities. Similarly, bureaucratic administrative procedures in universities, along with no R&D orientation among firm managers, constrain collaboration between academia and industry, limiting the innovation needed for SMP implementation.

In practical terms, this study identifies the crucial environmental and social priorities and provides an effective roadmap for coordinated action among policymakers, financial institutions, industry leaders, and developers. The proposed strategies stress the need for systematic interventions across multiple levels rather than isolated initiatives.

Despite its various contributions, the study is not without limitations. First, it relies on semi-structured interviews and qualitative analysis for in-depth insights into SMP barriers in food manufacturing. The findings reflect only the participants' views and do not represent the entire Egyptian food manufacturing sector. Future research could employ quantitative or mixed-methods designs to prioritize barriers and enable the drawing of stronger, even more valid inferences [75,76]. Second, although saturation was reached, the sample included relatively few managers of firms. Larger samples could strengthen the robustness of the findings. Third, this research describes a single national context. Comparative studies across countries could provide insights into how different institutional and cultural contexts shape the sustainability barriers. Finally, while this study developed a holistic, multi-level framework of barriers, future research could examine specific barriers in greater depth to explore their underlying causes and mechanisms.

6. Conclusions

Sustainable manufacturing offers firms the opportunity to improve social performance, long-term industrial competitiveness, and reduce their impact on the environment. Our study developed a multi-level framework that maps barriers to SMP in the Egyptian food manufacturing sector. It adds to existing research on sustainable

manufacturing by highlighting the often overlooked behavioral and socio-cultural factors, including institutional distrust, managerial mindsets, and socially embedded attitudes that may normalize regulatory avoidance and weaken engagement with sustainability initiatives. By uncovering the nature of these barriers and how they reinforce one another, the study helps explain why sustainability policies may stay "only on paper." To counter this effect, the study proposes actionable strategies, demonstrating that addressing multi-level barriers requires coordinated efforts among multiple stakeholders, rather than resting solely on individual firms or policy initiatives.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su182111441/s1, Table S1: Barriers to sustainable manufacturing practices identified in previous relevant research; Table S2: Categorization of barriers to sustainable manufacturing practices identified in previous research; Table S3: Company characteristics and sustainability orientation; Table S4: Interviewee characteristics; Table S5: Coding structure: initial codes and themes across the three levels of analysis; Table S6: Detailed actionable strategies for promoting sustainable food manufacturing practices; Supplementary Material S1: Semi-structured interview protocol. References [6,11,31–35,48,53,54,59,69,77–84] are cited in Supplementary Materials Tables S1 and S2.

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Informed Consent Statement: Informed consent was obtained from all participants prior to participation in the study, including consent for audio recording, where applicable, and for the use of anonymized data for research purposes.

Data Availability Statement: The data underlying this study are not publicly available due to confidentiality commitments to participants. The research data have been deposited in the University of Twente Areda research data repository under restricted access. Anonymized excerpts may be made available by the corresponding author upon reasonable request.

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