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A Biological Adaptability Approach to Innovation for Small and Medium Enterprises (SMEs): Strategic Insights from and for Health-Promoting Agri-Food Innovation

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Abstract: Adaptability has emerged in management/entrepreneurship literature as a business strategy to innovate, perform, and respond in a flexible manner to ever-changing contexts. Contemporary culture blurs boundaries between physical, biological, and digital domains, accelerating what entrepreneurship in sectors such as agri-food contributes to societal-scale solutions to problems at the convergence of social and commercial activities. In this study, we build upon the adaptability of biological systems to propose an approach to innovation, anchored in a tight, dynamic alignment between the strategic DNA of small and medium enterprises (SMEs) and the contexts in which they evolve. Our model employs interviews and supporting archival research on the health-promoting innovation practices of 37 SMEs in the agri-food sector. A two-year, single firm analysis illustrates its relevance and operational feasibility. Evidence suggests that the strategic DNA of SMEs, seen through the entrepreneurs' identity, informs behavior at various stages of the innovation process and the enterprise's evolution. Shifting identity prioritization is a reality, and interaction between entrepreneurial organizations and the environment is best understood as an interaction between the DNA of the entrepreneur/enterprise and the environment. This is valuable and will help agri-food and other SMEs to improve their ability to make the internal and external strategic adjustments required in a rapidly changing landscapes to create viable health-promoting food products.

Keywords: innovation; SMEs; biological; adaptability; agri-food; Québec; northeastern United States

1. Introduction

The most significant opportunities for business market development are linked to the most pressing challenges to overall well-being in the rapidly changing 21st century society (such as those related to green technologies or health-promoting innovation). Each comprises a set of interconnected, smaller components that cross boundaries between industrial (e.g., agriculture, food, transportation, healthcare) and societal (e.g., for-profit, non-profit, government) sectors. This presents an opportunity for strategic entrepreneurship to create value for individuals, organizations, and society [1]. With innovation accounting for 50% to 80% of all social and economic progress tied to modern development [2–5], it is only through *innovating the way we innovate* that we can go beyond what has been possible so far in societal-scale convergence solutions that create wealth in a way that also fosters lasting human and environmental health [5].

Small and medium enterprises (SMEs) in sectors such as agri-food are seen by consumers and society as key drivers for societal-scale solutions to challenges and possibilities at the convergence of social and commercial activities [6–8]. A new breed of entrepreneurs is more passionate about finding economically viable strategies for weaving human values into business strategies [7]. The key role played by entrepreneurs in modern development is not new [9]. They have been viewed as enjoying operational expertise, flexibility, and targeted knowledge [10], while operating with limited resources and capabilities [11]. However, challenges are manifold as only approximately half of them are still operating after the first three years from initial setup [12].

Adaptability has emerged in the management and entrepreneurship literature as a strategy for business to innovate and perform in an agile and flexible manner in the ever-changing contexts that characterize a 21st century that blurs the boundaries between the physical, biological, and digital domains. Adaptability is an important organizational concept and a key characteristic in biology. It enables genetic or epigenetic perturbations to cellular machinery so that the system functions desirably in the context of diverse and dynamic environments and experiences [13]. In this paper, we first review the organizational literature to enrich its contribution to model business and social development. This is done by way of adaptability in biological systems. We propose an approach to innovation anchored in a tight and dynamic alignment between the SMEs' strategic DNA (akin to the gene structure in biology) and the environmental conditions in which they evolve, enabling a dynamic evolution of business that remains rooted in the essence of what enterprise and entrepreneurship are about.

We apply the biological adaptability model using interviews and supporting archival research on the current innovation practices of 37 health-promoting SMEs in the agri-food sector, with an illustrative strategic analysis into the evolving dynamics of one of these businesses. Food is a powerful bridge between human biology and the agro-ecological, social, cultural, and economic contexts in which we live, be it in traditional or modern economies and societies. If agri-food innovation targeted by SMEs are to contribute to societal-scale solutions, it is optimal for them to address the following simultaneously: what consumers want; what they need for their vitality and health; what they can and want to pay; what the planet can offer sustainably; and which actors in the agriculture and food sectors can and want to produce in a cost-effective and economically viable manner [5,14]. The current practice of SMEs of various sizes helps us refine and operationalize our proposed model. We then follow up with one firm, apply the biological adaptability model to study its innovation strategies over two years, and evaluate the impact of its adaptive innovation process.

The last two decades of research and practice in business strategy and organizational behavior have underscored adaptability and the related dynamic concepts of agility and flexibility. They are core factors in a firm's ability to cope and thrive with rapid, relentless, and uncertain changes in a competitive environment of continually and often unpredictably evolving opportunities and challenges [15–17]. Adaptability was first examined at the individual level by Jean Piaget [18]. He defined it as the ability of an agent to change to fit different circumstances [18]. Adaptability mechanisms can be conscious or unconscious, as agents can actively learn (assimilate) or influence (accommodate) in an environment [18]. In organizational contexts, the concept was applied, for instance, in smart business networks, with a resultant model of adaptability comprising automatic responses, assimilation, accommodation, and environmental enactment [18]. Similarly, capability-based organizational adaptability can be understood as a key driver of competitive advantage. This impacts strategic flexibility, or a firm's ability to harness knowledge and capabilities in a changing market for new product development and commercialization [19]. Adaptability has also been integrated within resilience thinking as the capacity to adjust responses to external drivers and internal processes for stability [20,21]. Adaptability can be a process, action, or outcome to a changing condition, stress, hazard, risk, or opportunity [22]. Others suggest adaptability is the capacity to trigger and absorb cyclical and structural change, where flexibility is the capability to adapt to the components as they reactively respond or proactively anticipate changes in the environment [23].

Among adaptability mechanisms at the organizational level, agility can be understood as the interface between a firm and the market. It is based on delivering value to the consumer, being prepared for change, valuing human knowledge and skills, and creating virtual partnerships [24]. Agility has often been used to capture the ability of firms to overcome extreme threats and unexpected changes [15–17]. Organizational agility finds rapid and innovative responses to exploit changes as opportunities to capitalize on emerging business opportunities [16,17,25]. It extends the concept of strategic flexibility that handles unstructured changes [26,27]. Agility can take place by capitalizing on markets, which requires an entrepreneurial mindset, or operations, which requires quick implementation [15,28]. Agile firms must negotiate stability and flexibility to survive change and uncertainty [29].

Flexibility has also been linked to agility and adaptability [30] and can be conceptualized as the ability of organizations to predict, sense, and act on environmental change, which could be either taking advantage of opportunities or minimizing threats [31]. Adaptability and agility have also been linked to flexibility. Design for changeability incorporates flexibility, agility, robustness, and adaptability in a total system lifecycle. Here, flexibility represents the property of the system to be changed easily without undesired effects, while agility represents the property of the system to implement the required changes quickly. Flexibility is a prerequisite for achieving agility, and adaptability characterizes a system's capability to adapt itself to change in the environment to deliver functionality [32]. The IT Flexibility Framework is inclusive of both adaptability and agility and links them with anticipation. It prioritizes the leveraging of opportunities that come from external change and uncertainty while minimizing threats [29]. This builds on planned flexibility that identifies all critical areas in a project and plans for future reaction measures [33]. For SMEs, organizational flexibility has been attached to the quick adjustments necessary for survival [34].

The above review of the organizational studies literature addressing adaptability and the related concepts of agility and flexibility (grouped under adaptability hereafter) revealed adaptability as being responsiveness to environmental changes, but neglected to fully account for how the changes called upon by dynamic environments do or do not align with the core nature of enterprises or, most importantly, of entrepreneurs. Research has outlined that entrepreneurial passion and role identities provide context for firm behavior in changing environmental conditions. These include unconventional risk-taking, uncommon intensity of focus, and unwavering belief in a dream [35]. Further characteristics explored in this literature address: a personal belonging and identification with a company [36]; devotion and enthusiasm for a proposed business venture [37]; the desire to create something to make history and impact society [38]; an intense longing related to a work identity [39]; and the drive to overcome barriers [40]. These characteristics each have critical relevance in informing an understanding of the underlying nature or strategic DNA of the entrepreneurial firms. In fact, they may all be necessary for lasting economic success, particularly when the intent is that wealth is created while addressing social challenges. As mentioned earlier, we take SMEs interested in health-promoting agri-food innovation as a test bed for the development and application of the biological adaptivity model.

Adaptability is not only useful as a concept to inform strategic management; it is also a key characteristic of biological organisms. Biological adaptability enables genetic or epigenetic perturbations to cellular machinery so that the system functions desirably. This occurs in the context of diverse and dynamic environments and experiences [13]. Individual variation in adaptability depends on the integration of genetic and epigenetic, and environmental information for coordinated regulation of adaptation mechanisms across functional levels. In this task of deep, multi-layered contextualization of planned and unplanned variations in structure and mechanisms, information resides neither in the genes nor in the environment, but rather emerges from the interactions between these two disparate developmental resources (e.g., the individual and the ecosystem within which it evolves, with cooperation and competition among groups of individuals significantly shaping the evolutionary

dynamics). In turn, these integrated adaptability mechanisms explain individual variations in behavior and performance in different facets of life.

In the context of SMEs, the rapid evolution and growth in nature mimics the complex and dynamic interaction between organisms and environments described previously for biological systems. To survive and prosper in the dynamic business landscape and with changing consumer demands, SMEs have to integrate their leadership vision, core competitive advantage, and capability (corresponding to genetics in biological adaptability) with ongoing industry/market trends and differentiated consumer insights prior to defining their innovation portfolio (corresponding to environmental information) and must constantly adapt their leadership, operation, and business practices, as well as those of their surrounding network (corresponding to social dynamics and ecosystem in the biological model) as a function of real-time progress (e.g., analog to epigenetics). The concept of adaptability in biology is illustrative of SMEs' adaptive innovation progress. The biological adaptability model of innovation includes four pillars (Figure 1) with strategic DNA serving as an anchor guiding alignment with environmental conditions through the three other pillars of market challenges and opportunities, capabilities, and networks. In the next section, we summarize the relevant literature and discuss the importance of the four pillars of innovation for SMEs.

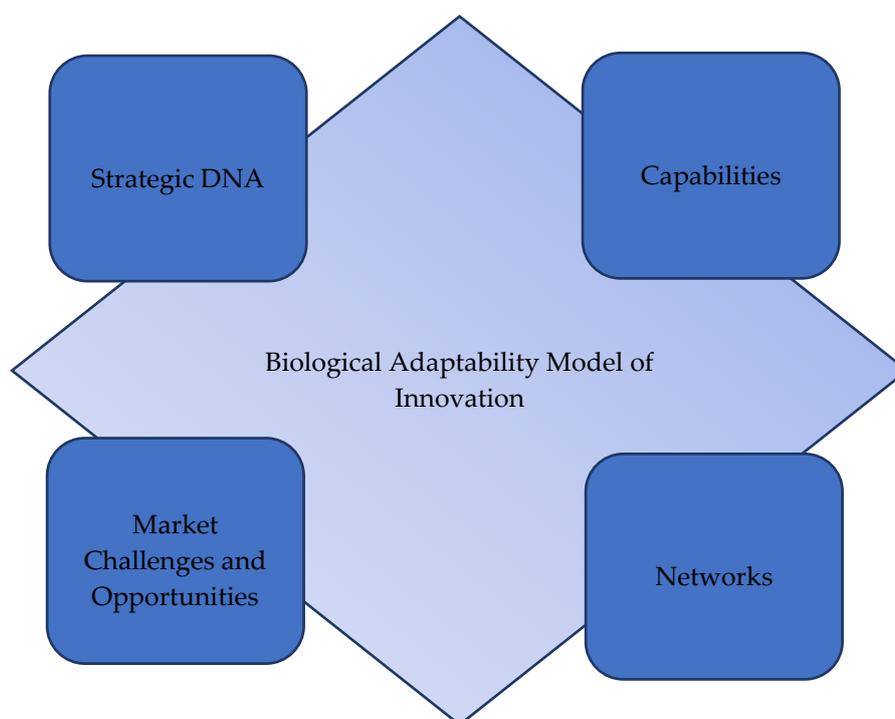


Figure 1. Pillars of the biological adaptability model of innovation.

In the context of SMEs, the core of strategic DNA typically lies in entrepreneurial passion tied to the business as a meaningful activity linked to self-identity [35]. There are three necessary facets based on identity that are relevant for the strategic DNA of firms. The first is an inventor identity based on an entrepreneur's passion for activities that relate to identifying, inventing, and exploring new opportunities. The second is a founder identity, where the passion is for activities involved in creating a venture or capitalizing on opportunities. The third is a developer identity, where passion is for activities that nurture, grow, and expand the venture [35]. As identity theory notes, individuals organize identities hierarchically based on centrality to self-meaning [41]. As a result, the three identities of inventor, founder, and developer may be viewed with different levels of importance by entrepreneurs and might also shift in salience over time [35]. In their lifetime, entrepreneurs will seek engagement with activities that confirm, and disengagement from activities that distract from salient

identities [42]. As shifting identity prioritization is a reality, the interaction between an entrepreneurial organization and the environment is best understood as an interaction between the DNA of the entrepreneur/enterprise and the environment.

This translates into the SME's learning philosophy, strategic direction, and trans-functional beliefs that guide their innovation strategies and actions [43]. The strategic DNA is comprised of human and structural components that are the results of these factors. Human components such as behavior and culture [44] address how ideas are generated [45]. These include the characteristics and attributes of employees such as leadership traits and competencies, along with broader behavior and values that are particularly valued, embedded business assumptions, and decision biases [46]. It has been shown that related behavior derived from supporting cultural beliefs influences organizational capabilities [47]. Entrepreneurial features and capabilities of the workforce are often linked to innovation [48] and are frequently exemplified in start-ups. Important aspects of this are a culture which embraces cross-functional teams [45] and the embedding of creative work environments [49,50]. Structural aspects are the components of strategic DNA that organize human and non-human resources and interactions (45,46). These include a formal reporting structure, decision authority, and information flows. Systems for planning, budgeting and compensation, and performance evaluation criteria reinforce the structures [46].

Firms are more likely to achieve long term success in today's changing environment when core knowledge is developed into capabilities. Core capabilities enable both specialization and synergy [51] to sustain firm prosperity [52] and maintain a competitive advantage [53]. Viewing capabilities as something that must adapt and adjust to environmental changes is widely accepted [54]. Firm performance depends on effectively managing core capabilities [52] to improve competitive advantage [53].

Dynamic capabilities can be understood as a set of specific and identifiable processes [55] that concern a firm's current or potential resources, such as knowledge [53]. They act as the organizational drivers for the creation and integration of resources into value generating opportunities [56]. Dynamic capabilities are relevant for small [57] and medium-sized [58] firms. In instances where SMEs have a robust set of dynamic capabilities, they are more likely to develop open innovation approaches [59]. This is particularly relevant in strengthening marketing resources, as most SMEs are not strong in this area [60].

Dynamic capabilities can be identified as adaptive, absorptive, or innovative. Adaptive capabilities are characterized by a monitoring of the environment [61], which works to identify and capitalize on emerging market opportunities [53] to anticipate shifts in market demand [55]. Absorptive capabilities concern the ability to learn from partners [53] and market events [55] by emphasizing the acquisition of external resources. Innovative capabilities occur when behaviors and processes allow for new products and markets to be created [53], and for technologies to be developed and integrated [55]. It is here that the reconfiguration of existing resources, and/or the integration of new ones occurs [61].

Business models provide, not only the canvas for alignment between entrepreneurial idea, passion, and strategic DNA with key capabilities enabling technologies and processes [62], but also guide the building of networks to support sustainable success. Business models address key partners, key activities, key resources, value proposition, customer relationships, customer segments, channels, cost structure, and revenue streams [63]. Business models can also be understood as the alignment of goals, templates, stakeholder activities, and environmental constraints [64]. At their most abstract conception, they can be viewed as a narrative of how a firm works [65,66]. Unsurprisingly, business model innovation often impacts the whole enterprise [67] and has become increasingly important due to the growing possibilities in their structure presented by technological development, changing market trends driven by consumer demand, and deregulation [68]. It can be understood as innovating the nature and the linkages/sequencing of the creation, delivery, and capturing of value generating activities between a firm and its network [69].

Networks represent the pattern of connections between individual parts or components that are linked together in a system [70]. Network members for SMEs include customers, suppliers, and partners [71]. A progressive understanding of innovation suggests firms are dependent on the

interactions between the internal and external orientation of a network [72]. Ultimately, SMEs create networks to increase competitiveness and innovativeness through benefits such as: obtaining new markets and technologies; delivering products to market more quickly; and accessing external knowledge [73]. For agri-food SMEs, collaboration and productive exchanges with network members is essential for success. These can include consumers, government, universities, and other private enterprises [74–76]. This represents the movement away from one-off transactions into embedded relationships that are mutually advantageous [77]. Relationships that result in the alignment of joint innovation outcomes, products, and services with a wider market and technological changes develop a strategic dynamic capability [78].

Over the last decade, platforms have emerged to facilitate continuous and circular feedback between network members [79] and across industries and sectors [80]. They contrast with pipelines that are characterized by classic value-chain inputs and outputs that occur in a linear series [79]. Platforms channel networks to create new value or experiences for all stakeholders [81] and include engagement, experience, and co-creation that is difficult to imitate [82]. They use open governance [79] to facilitate co-designing and producing of the next level of value for a product or service [83]. Interactions by network members on a platform allow for strategic developments that would not be possible using only closed innovation [84]. Among these, digital platforms with virtual environments are equipped to bring network members together [85] by using external knowledge and technology [52] to develop innovation communities and ecosystems [86,87]. The internet as a digital platform has positively impacted value co-creation with consumers at various stages of the innovation process [85,88]. It has influenced ecosystem branding, where firms offer a variety of different services while connecting with consumers under a single brand [89]. In the digital context, customer engagement networks consist of non-linear interactions between all members and can include non-purchase brand dialogue behaviors that range from exposure to interactivity [88].

SMEs make up over 95% of firms in the food and accommodation sector in developed nations such as Canada [90]. They are leaders of niche markets and in the past two decades have often been responsible for starting trends, such as those appealing to health and organic food consumption [91]. SMEs are more effective in meeting the needs of target markets such as the millennial generation [92]. Despite these advantages, three key forces have impacted the nature of the commercial environment and challenge the position of SMEs: digital technology; large manufacturers entering niche markets; and the emergence of non-traditional retailers.

The first force is the proliferation of digital technology and the subsequent emergence of the digital consumer [93]. This impacts the purchasing of products and services, which translates into increases in e-commerce sales [94,95]. While e-commerce has lagged in the USA at 4%, this figure is expected to rise to 20%, making investments in digital infrastructure essential [96,97]. In the era of digital consumers, which includes particularly savvy millennials [98,99], individualization of products and shorter time to market is essential [100]. The internet of things represents the idea of smart, connected products and the opportunities that broad technology infrastructure can create [101]. Digital-physical fusion could result in significant innovation in retailing for various smart appliances, such as refrigerators, and for the placing of grocery store orders remotely with selected retailers [102].

The second force involves large manufacturers entering previously established niche markets. Larger firms are making inroads into niche markets previously dominated by SMEs by purchasing and investing in smaller innovative brands [103]. For example, Nestlé uses acquisitions around the world to strengthen its organic offerings [104]. It also launched an incubator to assist agri-food start-ups so that they might become suitable acquisition targets [105]. Similarly, in 2017, Unilever invested in Sun Basket, an organic meal kit delivery service [106], and purchased the natural and organic small firm Sir Kensington's [107]. This type of activity also encourages mass distributors to enter niche markets, an example being Wal-Mart's development of a year-round designer cantaloupe [108]. SMEs are facing stronger market challenges and they must defend their market through innovation.

The third force is the increasing pressure from omnichannel retailers in a changing industry environment. For example, the lines between supermarkets and other retailers have become blurred, extending food selection. This began with Wal-Mart and various club stores in the 1990s [109] and continues today with digital enterprise. The acquisition of Whole Foods by Amazon represents a consolidation of agri-food retailing into a wider fusion of digital and physical retail experiences that will continue to impact how consumers make their choice of brands and products [110]. In response, a partnership between Wal-Mart and Google enables food to be ordered using voice recognition technology through Google Assistant [111]. Furthermore, Wal-Mart recently expanded pickup and delivery services and suggested they might use virtual reality components [112].

In parallel to these forces, food trends have increasingly made an impact on consumer purchasing decisions and innovation in the food industry. Trends represent responses to the convergence of an aging population, increases in chronic diseases, the emergence of food as medicine, and more educated and technologically connected consumers [113]. Consumers worldwide are becoming more conscious of the link between their health and food [114]. They are increasingly inclined to select products that have healthy attributes such as lower fat, sugar, and sodium content [115], which are natural, organic, and have no added chemicals/pesticides [116]. Consumers are also moving towards functional foods that offer additional benefits not found in conventional foods [117,118]. This includes supplements that contain nutrients or substances that have a nutritional or psychological effect beyond what could be achieved in a regular diet [119].

2. Materials and Methods

SMEs were interviewed to understand how their innovation practices in general and those specifically targeting health-promoting food related to the four pillars. We used a judgment sample; one author, in collaboration with business contacts, sent out interview invitations to SMEs located in Québec and New England. The SMEs were selected according to the appropriateness and availability of professional contacts to the author, and representation of diversity in the agri-food industry. Among them, 37 SMEs agreed to participate in the 2015 study, including 21 small (under 100 employees) and 16 medium-sized (over 100 employees) firms. The SMEs were from a diverse set of industries, including vegetable, fruit, meat, poultry, seafood, dairy, cereal, beverages, condiments, and snacks. This diversity helped to better capture the ways in which SMEs adapt their innovation process and develop health-promoting food.

To operationalize the proposed model, we first developed an interview grid consisting of questions that focused on a firm's innovation process alongside health-promoting food. The questions corresponded to the biological adaptability model and addressed strategic DNA, capabilities, networks, and market challenges and opportunities. Questions concerning strategic DNA focused on the type of markets being targeted (local, national, international), the funding structure, a start-up/entrepreneurial culture vs. a corporate one reflected by organizational structure and employee duties and relationships, the length of the innovation process, and radical vs. incremental innovation. Questions regarding capabilities addressed the type of expertise firms possessed, focusing on the skills of different departments (marketing, R&D, operations). The role of committees that brought departments and specialists together were also discussed, as were the methods by which market research was conducted. Questions concerning networks explored open vs. closed innovation and gathered information explaining the nature and depth of external relationships. The presence of business model innovation, and whether it involved external partners, complimented this. The role of digital platforms in integrating stakeholders through various stages of the innovation process was explored. Finally, questions regarding market challenges and opportunities considered trends in health and nutrition (naturalness, reductions, fortifications, organic, etc.) and their level of importance and adoption by the SMEs.

Interviews with SMEs ranged from 30 min to 2 h, and most took approximately an hour. The research was approved by relevant ethics committees, and we obtained consent from each

firm. The respondents varied in age, sex, educational background, and position within the company. The 37 interviews were conducted with the aim of providing general information regarding market trends and the components of the innovation process. Questions were augmented by secondary resources such as internet websites and the popular business press [120]. Answers were recorded and coded using NVIVO software. Each firm's innovation process was accessed based on the proposed adaptability model shown in Figure 1.

To better understand the drivers of adaptive and health-promoting innovation, a series of interviews with an SME that participated in the first set of interviews were carried on over the 2017-2018 period. Khloros granted permission to be identified in this study. They agreed to discuss how they adapted their capabilities and strategic DNA to improve their market situation while in the process of implementing open innovation through a collaborative digital platform.

Khloros is an illustrative case study that shows how the biological adaptability model can be used to demonstrate an enterprise's core adaptability. The illustrative case is informed by the principles of strengths, weaknesses, opportunities, threats (SWOT) analysis (which supports an improved understanding of how the core adaptability drivers operate). Khloros' strategic DNA included a core R&D capability along with an inventor identity. However, it had structural weakness in marketing and strategic DNA and required an 'epigenetic' integration of founder and developer identity to develop the marketing capability required as it evolved.

3. Results

Results are first presented for the 37 interviews in terms of the four pillars of the biological adaptive model, followed by the SME-specific illustrative strategic analysis.

3.1. Strategic DNA

Three main entrepreneurial identities of inventor, founder, and developer [35] are singly and collectively defining key structural and human components of the strategic DNA of agri-food firms. An exploration of market orientation also complements the analysis of the structural components of the strategic DNA [45,46]. A slight majority of SMEs were designed to pursue local or national niche markets (21 with 16/19 small and 5/18 medium), while others (16 with 3/13 small and 13/18 medium) targeted mass markets connected to national and international consumers. This is salient as the results suggest that most small firms are shaped by inventor identity, while most medium-sized firms have a combination of founder and developer identities [35]. This is crucial as small firms need to react to the potential entry of large manufacturers into their market [102].

The funding structure also informed the structural component of the strategic DNA [45,46]. Many SMEs were funded primarily by internal resources (14/37), with small firms more likely to be funded this way, with 10/19 cases reflecting this versus 6/18 medium-sized cases. In contrast, government funding was secured by more firms (16/37), with medium-sized firms dominating. Governments gave 7/19 small and 9/18 medium-sized firms financial support; 5/19 small and 2/18 medium-sized firms received funding directly from a provincial/state level government and 2/19 small and 7/18 medium-sized firms received tax credits. A small firm received support from family and friends while a medium-sized firm was assisted by manufacturers in their industry. Additionally, 5/19 small and 5/18 medium-sized firms had more than one funding source. These results reinforce the idea that small firms were more likely to have an inventor identity, as the capitalization and expansion seen in founder and developer identities is more consistent with seeking out diverse funds [35]. A participant from a medium-sized firm stated: *'We do go for a tax credit on anything that we do for innovation.'*

Human components of the strategic DNA that supported the innovation process were also found in firm culture and were discussed [44,46,47]. Some firms had a start-up structure (21 with 17/19 small and 4/18 medium) while others had a corporate one (16 with 2/19 small and 14/19 medium). These results further suggest that small firms are more likely to have inventor identities [35] and are

better positioned to respond to market trends than their medium-sized counterparts [48]. The dynamic nature of entrepreneurial start-up culture in small firms was captured:

'There are two partners here. My role is more product development and quality control. I also oversee the day to day bookkeeping and accounting, and participate in sales. We all do that. You almost wear every hat in the company, although my background is not in technology; that is my partner's forte.'

The time taken for the innovation process was outlined by 18/37 SMEs (9/19 small and 9/18 medium); 5/19 small and 2/18 medium-sized firms took less than a year and 4/19 small and 7/19 medium-sized firms took longer than a year. A further 19 SMEs (10/19 small and 9/18 medium) had no typical timetables for their innovation process. The longer development time suggests that some medium-sized firms had a developer identity [35]. A participant from a medium-sized firm stated:

'From the time that you get that formula locked down and this is the flavor we want, this is the recipe we want, it could be a year before you're ready to launch. You have to wait that one year just to make sure the product's going to hold up, then you can start designing it and putting on the marketing material that you need and getting the sales staff trained.'

Radical (changing the structure of the market or creating a new market) and/or incremental (minor adaptations) innovation [121] was used by 25/37 SMEs (13/19 small and 12/18 medium). The use of radical and incremental innovation occurred simultaneously in 10/37 firms. Small (3/19) and medium-sized firms (7/18) used both, which suggests the presence of a founder identity that both creates and capitalizes on opportunities [35]. Some small (6/19) and medium-sized (5/18) firms fused incremental innovation, suggesting an inventor identity [35]. A group of small firms (4/19) used radical innovation, pointing to a minor presence of developer identity within the group [35]. A participant from a small firm described its use of radical innovation: *'We have bought software from a company, to have traceability'*, along with its use of incremental innovation: *'We designed a new bag for harvesting two pounds (instead of one pound) of seafood.'*

3.2. Capabilities

The central core capability essential for each firm's competitive advantage was identified [53]. The most prevalent was R&D (17 with 10/19 small and 7/18 medium). Marketing expertise was scarce as a core capability (5 with 3/19 small and 2/18 medium). Overall, 13 firms (2/19 small and 11/18 medium) were explicitly committed to constantly improving their selected competencies [52,54]. For example, on its website, a medium-sized firm demonstrated that it engaged in peer-reviewed research to ultimately optimize product quality and effectiveness.

Most SMEs (22 with 8/19 small and 14/18 medium) incorporated multi-department committees in their innovation process. Despite the infrequency of marketing as the core strength, it was used by most firms in their innovation process (25 with 13/19 small and 12/18 medium), which is a reflection of its importance in dynamic capabilities [53,55]. In committees, marketing was most frequently combined with R&D (19 with 12/19 small and 7/18 medium) followed by operations (13 with 9/19 small and 4/18 medium). The pairing of technical strengths with weaker marketing abilities represents a work in progress for many firms in constructing strong innovative capabilities [53]. A salient example of integrative committees supporting innovative capabilities was explained by a participant from a medium-sized firm: *'They work on ideas, chip in as a crew. Accounting, operations, marketing, and salespeople. Instead of just having everything come from one department. It's definitely more collaborative.'*

Firms of both sizes employed various industry research to learn about health-promoting food trends. The most common methods included market observation (26 with 14/19 small and 12/18 medium), market research (10 with 4/19 small and 6/18 medium), direct consumer feedback (20 with 9/19 small and 11/18 medium), and food shows (15 with 7/19 small and 8/18 medium). The breadth of methods used illustrates that many SMEs have successfully cultivated adaptive and absorptive dynamic capabilities [53]. A participant from a medium-sized firm explained how they

integrated multiple methods: *'We have a person who works on consumer insights and looks at survey data from our actual customers, market trends, and what's going on in our industry.'*

3.3. Networks

SMEs tended to pursue closed over open innovation. External resources were used in a more traditional closed innovation manner by 18/19 small and 14/18 medium-sized firms. A typical example of closed innovation was seen in a small firm: *'I have a consultant in product technique that helps us; it is a reference too. When I had problems in reducing salt, he referred others to me.'* When pursuing open innovation, business model innovation in concert with network members [69] such as customers, suppliers, and partners [71] was implemented by 7/19 small and 6/18 medium-sized firms. An example of this was found in a medium-sized firm's relationship with a university: *'We collaborated with a university and the research generated was exclusive to our product and not applied elsewhere.'*

According to participants' comments and supplementary information found on their websites, some firms (25/37 with 12/19 small and 13/18 medium) engaged with digital platforms to cultivate relationships with their consumers and other stakeholders. Facebook was the most common (24 with 11/19 small and 13/18 medium) and was used to communicate product launches and marketing campaigns, and to share health information. These interactions largely reflected co-creation at later stages of the innovation process [88].

3.4. Market Challenges and Opportunities

Most of the SMEs that were interviewed have been responsive to consumer-driven trends that concern health [91]. While small firms focused more on making natural products (20 in total with 14/19 small and 6/18 medium), medium-sized firms were more likely to focus on reducing undesirable ingredients from their offerings to improve health (22 in total with 6/19 small and 16/18 medium). A participant from a medium-sized firm reflected: *'Due to wider popularity, we developed a very low-calorie product with sweetener instead of sugar.'* This is logical as medium and large-sized firms are moving in the direction of healthier food products previously occupied by smaller firms [115]. Enhancements and fortifications of ingredients such as vitamins, protein, minerals, and fiber to improve health were equally implemented by 10/19 small and 10/18 medium-sized firms. A medium-sized firm illustrated how it was using enhancements to create a unique product with a competitive advantage: *'Vitamin D in our product is something that you do not normally find.'*

3.5. Model Refinement

The interviews illustrated that the 37 agri-food SMEs were adjusting to market trends and changes in the industry, albeit with varied responses. In terms of health-promoting innovation, naturalness, enhancements, and reductions are the trends that received the most attention. Most pursued adaptive and absorptive capabilities rather than innovative ones, and often achieved this through resource integration. Multi-disciplinary committees were frequently present and anchored in R&D and marketing, with this pairing being more prevalent in small firms as medium-sized firms often had participation from additional departments such as operations, sales, and accounting. This pattern of arrangement is noteworthy as it is an attempt to address a general lack of sophisticated marketing expertise. Overall, weaknesses in marketing expertise for SMEs ultimately prevent the development of strong innovative capabilities.

The interviews also revealed small firms were much more likely to have a start-up structure and were better positioned to innovate as they were able to adapt to consumer trends. However, most SMEs did not implement open innovation practices, nor did they engage in business model innovation. The combination of business model innovation and digital platforms in medium-sized firms was more prevalent than in small firms. It was encouraging that most SMEs used digital platforms to cultivate relationships with their customers and network members as an appropriate market response. Unfortunately, this development has not yet impacted the earlier stages of the innovation process in

a significant manner, although the combination of business model innovation and digital platforms was more prevalent in medium-sized firms. In summary, the interplay between processes, culture, and innovation is important but is in its nascent stages for most agri-food SMEs.

These results from the interviews provide a foundation for us to operationalize the four pillars of the model. Table 1 summarizes the above discussion and presents the indicators that were extracted from the interviews and should be relevant when assessing each pillar. We then applied this framework to thoroughly study one firm's adaptive innovation strategy.

Table 1. Indicators Derived from Interviews.

Pillar	Indicators
Strategic DNA	Niche vs. mass market Funding structure Start-up vs. corporate culture Length of innovation process Radical vs. incremental innovation
Capabilities	Core knowledge Innovation committees Industry research
Networks	Open vs. closed innovation process Business model innovation Engagement with digital media platforms
Market challenges and opportunities	Food innovation's naturalness Nutritional and other attribute enhancements Negative attribute reductions

3.6. An Illustrative Case Study of Adaptive Innovation: Khloros Innovation and the Creation of a Chewable Functional Product Category

A further set of interviews in 2017 and 2018 took place with a firm from the initial set; Khloros Innovations. It was selected because it offers health-promoting products, its innovation process is currently in development, it is making the transition from local niche to international markets, it was the firm that most exemplified a strategic push towards open innovation by developing learning networks and cultivating leadership, and it adopted multiple entrepreneurial role identities. Two formal semi-structured interviews took place in 2017. One was with the CEO while the other was with the digital platform manager. Another follow-up interview took place in 2018 with the digital platform manager. The interviews were conducted to gain an understanding of how the firm adapted its innovation process to define and differentiate its product offerings to the target market. It also provided responses to an engagement in experiential learning with a co-author. Prior to the formal interviews, we sent our discussion guidelines that were evaluated by a relevant Khloros strategic innovation committee. Questions focused on the drivers in the model (Figure 1) and addressed the profile of the enterprise, market challenges, capabilities, technology, product portfolio, and innovation process. With this information, Khloros considered their potential responses. Discussions revealed the development of the firm's open innovation processes. Phone calls with the participants were also made between the formal interviews to validate the information. We drew on principles of SWOT analysis to explain the illustrative case study.

3.6.1. The Need to Adapt: 2015–2016

The first 2017 interview took place in the fall to get a better understanding of Kloros' challenges, capabilities, and strategic DNA. Khloros began as a technology firm with its main strength being a knowledge-based dynamic innovative capability [53] of R&D. This was reflected in strengths in developing a new technology, originality of concept, and in persuading partners to help develop the market. More specifically, a technological dynamic capability [55] was developed by partnering with

laboratory researchers who created a technology that promotes rapid buccal absorption. In other words, the product improves the positive effects of chewing naturally to deliver faster bioavailability of active ingredients through the mouth, enhancing buccal absorption for fast action. It can be used in a versatile way and for different food ingredient bases. The firm's weaknesses were situated around a lack of structure and rigorous governance of innovation processes, the limited in-house means of creating a step-by-step analytical business plan including innovation analysis and marketing evaluation, and a lack of rigor and objectivity in the testing of its products. With these weaknesses, it was not possible for a small enterprise such as Khloros to compete and succeed in a high-tech industry with sophisticated and very well-equipped competitors. A deeper transformation of the firm's strategic DNA through improvements to innovation culture, structured governance of innovation, and market access was required. The firm's original entrepreneurial identity was heavily geared towards the inventor type, as they were mainly focusing on technological development and proof of concept [35]. Khloros aimed to capitalize on market opportunities [91] available in the growing health-promoting food sector, lifestyle improvement, and the niche segment of individuals who wanted the benefits of functional products such as energy drinks without purchasing those specific products. The threats it faced were potential competition from more established firms and negative consumer perceptions of similar functional products such as energy drinks.

Khloros applied its technology to chewable tablets to develop products to meet the needs of the consumers for energy, concentration, and sleep. The firm rapidly created the spinoff brand 'Chewpod' as its value-added component to test the market and branded the product. As Khloros did not have strong marketing management capabilities [60], there was continued trial-and-error and many unsuccessful attempts to develop an effective marketing strategy. This was largely captured by a struggle to clearly define the product category. While it could be a substitute for an energy drink, the tablets could not be defined as a gum, drink, or drug. Ultimately, the product was released without an in-depth precompetitive analysis and lack of knowledge of the characteristics of the industry, main competitors, and market segmentation. The marketing evaluation for message, market, packaging, and segment was not well defined or understood by the owners. This represented an attempt by the firm to embrace founder role identity components such as a focus on commercialization [35]. Khloros initially distributed Chewpod in pharmacies, natural product stores, supermarkets, and convenience stores to sales results that did not meet expectations. Products were available locally, but consumers and distributors were unable to clearly understand the benefits and added value. Negative comments from a food expert in the press followed due to the product being associated with energy drinks. It was defined as a 'Carburant à mâcher' with the slogan of 'Reach Your Peak.' Its product category was situated between energy drinks and chewing gums, which created confusion. This occurred due to an inability to fuse a capability in R&D with the acquisition and integration of required marketing expertise [53]. The focus was more on the technology itself rather than adapting to industry requirements and commercial practices.

Khloros continued to be skewed towards an inventor identity [35] focused on its technological innovations. However, the firm was motivated to adapt because they tried to market the product without really understanding the market, the competition, and the industry. Khloros initially tried to resolve these issues internally without achieving sales expectations. The firm realized they needed to build a more innovative culture. In the summer of 2015, Khloros realized that the in-house team misunderstood the market complexities and they started to search for solutions externally. For assistance, they turned to participation in an extensive innovation program for agri-food SMEs. The program exposed the firm to trends in managing innovation and supported them in developing their strategic analysis process.

Involvement in the innovation program represented the first real embrace of developer identity characteristics. This assistance represented attention to the nurturing and growth of Chewpod [35]. Participation in the program worked to create an objective analysis of the problem. During their participation from 2015 to 2016, the diagnosis was that they did not position themselves in the

market effectively and did not successfully communicate the benefits of the product to the target market, and the product category was not a good fit. Essentially, Chewpod was not identified in the minds of consumers as offering differentiated functional benefits. The development of dynamic capabilities related to marketing was implicitly suggested [55] by noting potential market advantages, but these were not well promoted, and the firm needed to redefine the market, translate benefits, improve distribution, and understand the consumer better. There was a need for more objectivity and learning, and a need to obtain the benefits of having outsiders question process and strategy. The firm needed to reassess their strengths in technology (lack of testing rigor) alongside their weaknesses in marketing. In response, a new brand image and market positioning was developed in the fall of 2016.

Ultimately, participation in the innovation program triggered the decision by the founders to network with outside experts and develop a clear mandate to formalize open innovation, develop a clear business plan, and build a team with new leadership who possessed the expertise needed for international partnerships. The firm needed to enrich its strategic DNA and transition from an inventor to a founder identity.

3.6.2. Adaptive Innovation: 2017–2018

Two additional semi-structured interviews took place in the fall of 2017 and the winter of 2018 to inform the nature of the innovation process through its various stages of implementation. The managers' inputs illustrated the process by which the firm re-oriented itself to achieve its goals by restructuring the innovation process and business model to maximize competencies, improve innovation culture, and develop networks through digital platforms. These efforts represented a maturing of the entrepreneurial identity of Khloros. While they retained their passion for technical invention, they strove to effectively commercialize and grow.

The new CEO confirmed they lacked the required expertise in marketing and communication [122], and new learning was not incorporated into daily work and processes [43]. Firm advantages, such as the proactive use of digital technologies and platforms, were not effective due to a lack of understanding of the customer experience and how to build value from it. With the new CEO, Khloros took the necessary actions to update both its marketing capabilities and the strategic DNA of the firm. This involved the firm adapting by modifying its business model to align desired capabilities with appropriate human resources. The maximization of human resources was achieved by improving communication, switching from a pipeline to a structured open innovation process, and using platforms to facilitate networks and the embracing of open innovation. Each of these actions was made possible due to modifications in the entrepreneurial identities prioritized by the firm. They represent the realization within the firm of the importance of modifying its strategic DNA to include necessary developer components.

A new innovative business model was developed in the summer of 2017, which altered the nature of the value generating activities between the firm and its network [69]. The firm sought to align [62] strengths in R&D and product technology with a greater understanding of the consumer experience, increased marketing capabilities, expansion into international markets, and the use of platforms and networks to achieve it [63]. The new CEO envisioned achieving this through two complimentary strategies. The first involved developing an interactive platform to communicate with consumers and market actors. This was done to transition, support, and accelerate the shift to open innovation. The second involved engagement with Master of Management- Marketing students to define the product, its appropriate category, and relevance to consumers. The firm's strategic DNA needed to be tweaked, with a revision of leadership and enrichment of human resources being identified as essential for organizational capabilities to be enriched [47]. This reflected their cultivation of new developer identity characteristics alongside the inventor identity foundation [35]. Significant personnel changes were made at the senior level, with half of the senior managers leaving due to discomfort with the new business model. The mandate of the new senior management was to find employees with the desired characteristics and motivations [46]. Priorities were given to positions that used digital media to test

products and which would strengthen marketing capabilities and engage in more direct interactions with consumers.

In the winter of 2017, the firm presented its new concept to Master of Management- Marketing students. Khloros desired some quick advice from expert consumers regarding the new image to see if it had adapted to their target market of millennials. After feedback, the firm realized that while their branding was improved, segmenting based on demographics was the wrong approach. Rather, consumer lifestyle characteristics were more important. This represented a small but significant first step in the firm, addressing its marketing issues and absorptive capabilities [53]. The interaction made the firm realize they needed to establish a closer, more interactive process with its consumers to develop a more effective strategy.

Khloros embraced open innovation by incorporating an active digital community into its strategy. Some external partners were interested in an open innovation approach while others were not and elected to no longer partner with the firm. Once relationships were clarified, Khloros pushed forward with an external firm that created a new website that enabled stakeholders to communicate with one another on a platform. Basecamp software was used by all collaborators and was the only requirement for potential partners. This was a crucial step the firm took in developing an interactive network to accelerate the speed of its actions.

The process components of the strategic DNA also needed to be adapted to maximize new human resource capabilities. The organizational structure was still deficient as there continued to be a lack of process efficiencies. The lack of efficiency, derived from poor communication between R&D and marketing [45], was addressed by introducing the idea of learning, doing, and pacing. This adaptation improved teamwork between specialized departments:

'I said we are going to make it simple: Learn; Do; and Pace. What are we learning every day, every week – can we communicate it? Can we change things that did not work? And can we do the pacing? If we cannot do these three things, we do not have a business. It got everybody on board.'

(CEO, Khloros Innovations)

The 'Learn, Do, Pace' construct was well suited for a platform approach that considered all possibilities in each innovation stage and enabled the integration of personnel in R&D with marketing in the innovation process [55]. This meant that communication, sales, and innovation were successive parts of a formalized order, which was salient as the structure represented a means to effectively organize and integrate inventor and developer identity characteristics [35]. The shift led to clarifying the product technology to align with Basecamp software and the development of a collaboration with a foreign partner in the fall of 2017. This worked to improve firm self-perception, and new markets in the western USA and North Africa were targeted. Despite these adjustments, the firm was still unable to clearly define the added value for consumers.

Value generating activities between Khloros and Master of Management- Marketing students engaged in innovation consulting work took place again in the fall of 2017. This engagement represented an ongoing open innovation process. From September to December, students could share information and communicate with Khloros managers on its Basecamp platform. In addition, Khloros met the students three times over that period to give more in-depth feedback. The group represented members of the target market [76], and Khloros was keen for their input, specifically requiring assistance in properly defining the product category. The students considered that the added value had similarities with power drinks such as Red Bull and chewable products offered by Wrigley. However, the technology Khloros created assimilates the function almost immediately and more quickly. In December, the students suggested an appropriate definition would be a 'Supplément à mâcher' or chewable supplement, which would position the products in their own category. Ultimately, this interaction with the target market increased the firm's efficiency in a later stage of the innovation process [89]. It represented the co-designing of the next level of value for the product [84] by making it easier to explain the benefits of the technology and the unique category to distributors. In practice,

the platform contributed to the acceleration of the firm's development and laid the groundwork for positive outputs for further partnerships with external actors in its network [72]. It demonstrated that Khloros was able to successfully integrate characteristics of developer identity to increase the chance of success for their venture [35].

Khloros works well as an illustrative case study because it is reflective of the need for SMEs to obtain external feedback to adapt effectively. To integrate external ideas and solutions, it required a culture change found in a structural DNA characterized by an agile, innovative organization. Khloros struggled to evolve from a firm with an inventor identity to one that incorporated founder and developer characteristics. It consistently needed to complement its efforts in embracing open innovation with a more structured approach centered around 'learn, do, pace', where governance structure and innovation culture could embrace external feedback.

4. Discussion

The results of this two-level analysis of SMEs in the agri-food sector are generally supportive of the strategic relevance and operational feasibility of translating the four key pillars of the biological adaptability model of innovation into actual industrial practices and processes. The results of the first level analysis of the 37 health-promoting SMEs reveal some of the gaps that exist and prevent the agri-food sector from fully tapping into the possibilities of adaptive innovation. In most cases, entrepreneurial identity and innovation culture influenced process. For instance, strategic DNA as an analytical lens reveals that the inventor identity is reinforced in most small firms through their orientation to local markets, the primary use of internal funding, and the presence of a startup culture [35]. Medium-sized firms exhibited behavior that was more in line with founder and developer identities, such as pursuing a wide number of markets and seeking diverse sources of funds [35]. Firms of all sizes flirted with radical and incremental innovation, suggesting either the presence of founder and developer identities or the potential for an inventor identity to evolve [35]. An examination of the relationship to networks supports the idea of a cautious move towards pursuing open innovation in collaborations [72], with only a small number of mostly medium-sized firms selecting this route. In fact, a vast number of firms selectively pursued co-creation at later stages of the innovation process. Firm capabilities [59] were heavily skewed towards R&D, with marketing often relegated to multi-department committees populated by technical experts. This primarily occurred in medium-sized firms. With respect to market trends [91], small firms mostly pursued market opportunities in naturalness, while medium-sized firms tended to emphasize reductions. Taken together, the results show that characteristics of the inventor identity found mostly in small firms resulted in primarily closed, internal innovation. The founder and developer identities found primarily in medium-sized firms supported behavior that was more open; however, in practice these behaviors took place as limited, disjointed actions.

These interviews reveal barriers that need to be overcome in terms of underlying value creation logic and organizational practices, as well as mental barriers in employee and leadership mindset—barriers that have also been observed in the domain of green innovation [123]. However, the illustrative analysis of one of the SMEs that decided to fully embrace an innovative approach that brings together the four pillars of adaptive innovation suggests the advantages of the adaptability model. We have built an ecosystem to bridge the many disciplinary and sectoral silos needed to continuously innovate, experiment, and learn from successes and failures in different products, processes, business models, and leadership styles. As such, the adaptability model succeeds in ensuring a firms' relevance, much along the lines of what biological adaptability entails in leading to successful evolution that not only ensures survival, but also generates thriving diverse and dynamic conditions and experiences.

The biological adaptability model of innovation for SMEs builds upon the many shapes taken by open innovation for SMEs, including those that emphasize ecosystem building [124], those that are integrated into a linear stage-gate process model of new product development [52], and others that entail broader inbound and outbound transformation of research and development [125–127] and

strategy [86] in SMEs and larger firms. From the perspective of the agri-food industry, the model's results suggest that small agri-food firms tend to have an inventor identity focused on R&D and natural products. In contrast, medium-sized firms are more likely to include developer identity characteristics, integrate marketing capabilities alongside technical specialties, and practice open innovation. Thus, small firms in agri-food and other sectors should give more attention to the evolution of their internal identity to avoid yielding capability, network, and market advantages to their medium-sized competitors.

The product positioning and channel building strategies observed by Chewpod are each informative in revealing how SMEs can act as key catalysts not only for innovation in larger businesses but also in transforming markets and institutions. Khloros' journey from a firm with a strong but narrow identity centered around a technological research capacity to one that expanded its capabilities and engaged in open innovation was informative. It illustrated how agri-food and other SMEs can cultivate a new entrepreneurial role identity to complement a core strength [35]. The positioning of the product innovation as a chewable and functional health product opened a new product category to generate consumer interest and meet consumer health needs, with a breakthrough biotechnology innovation that was neither in existing food product categories in consumer minds or on the grocery shelves (gums or natural products). Khloros' current partnership plan includes working with large multi-national corporations to explore deeper and broader penetration of their existing product lines and expansion into a new type of food product, akin to chocolate with major industry players. Such initiatives offer great potential as evolutionary collaborative models for improving opportunity recognition and breakthrough innovation. This can occur not only in SMEs but also in large established firms and throughout the whole ecosystem. It creates the possibility of driving supply and demand for food along with health and self-management [128].

Finally, it is important to note the key role that big data, artificial intelligence, and other digital technologies may play in accelerating adaptive innovation in agri-food and other sectors. Possibilities do not solely arise from the individual mining of biological material of food and human health and disease. They are also generated by bridging these to extract insights from the user-generated and crowd-sourced text corpus in social media on consumer's belief systems, perceptions, and other facets of consumer choice and experiences [129].

This paper improves the literature by refining the strategic DNA concept to emphasize the role of entrepreneurial identity and passion. The biological adaptability approach gives more weight to the entrepreneur, along with their influence and managerial preferences, rather than focusing solely on a firm's structural characteristics. Furthermore, applying this approach to the agri-food sector is novel. The influence of various strategic DNA orientations amongst collaborating organizations is a logical next step of inquiry.

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