Available online at www.centmapress.org

INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Int. J. Food System Dynamics 9 (2), 2018, 138-148

DOI: http://dx.doi.org/10.18461/ijfsd.v9i2.923

Food Futures and 3D Printing: Strategic Market Foresight and the Case of Structur3D

Sylvain Charlebois[1] and Mark Juhasz[2]

[1]*Faculty of Management, Rowe Management Building, Dalhousie University, Halifax, Canada*
[2]*The Food Institute, University of Guelph, Canada*
Sylvain.charlebois@dal.ca

Received November 2017, accepted March 2018, available online March2018

ABSTRACT

Our case study analyses 3D Printing and its contribution to food innovation. Our examination uses strategic foresight as a knowledge transfer tool for food industry planning. As a force for change, customization is a leading characteristic of 3D food printing in user-centred design. Broader societal and economic pressures for sustainability, human health and nutrition can be addressed by 3D food printing with bioplastics, recycling, and product customization catered to distinct market demographic segments. In terms of scale and competition, some 3D food printing companies will focus on customization at scales for purposes. At regional or national authority levels, innovative policies will serve vital incentive catalysts and support structures. Our case study looks at Structur3d, a Kitchener-Waterloo-based company, within a larger world of 3D printing innovation, science, and processing. We examine Structur3d in the context of food innovation at-large within an ecosystem of economic change and disruption, and consider the evolution of Canadian food business, manufacturing strategy and public policy in a global economy to meet rapidly changing societal needs in engineering, capital, material science, and action planning.

Keywords: 3D food printing, food processing, market development, innovation, strategic foresight.

1 Introduction

A variety of novel technologies have attracted the attention of industry, consumers, and policymakers in recent years. Many wondered how they might impact future food production practices. Some have argued that the 3D printing revolution has the potential to significantly reshape manufacturing ecosystems and has been tagged to grow to an $8.4 billion U.S. market by 2025 (Lin, 2015). 3D printing can be particularly impactful in the short term for products that are in smaller, more customized volumes and with greater cost-tolerance to the end-consumer (Vicari & Kozarski, 2013).

On the leading edge of food and material science application, 3D printing offers unique and creative opportunities; however, it will need to address challenges to performance, costs, printing speed, customization, and scale (ibid, 2013). In terms of what advances 3D printing can deliver to food innovation, questions related to safety, ethics, and consumer perception will be important factors. Critics might currently envision the technology as limited to researchers, hobbyists, and enthusiasts, but proponents emphasize how 3D printing aids in manufacturing iteration, prototyping and innovation trends in mass customization (Sun et al., 2015).

While there are numerous types of 3D printing technologies and applications, this case study looks at Structur3d, a Canadian-based company, within a unique business ecosystem focused on extruding and printing fluid materials. In this context, we attempt to see how 3D food printing can enhance the use of new technologies and offer innovations, and perhaps new business models. (Vicari & Kozarski, 14:2013).

First, this case study will address the major issues that arise with the growing prospects of 3D printing, and the potential value 3D printing offers to the economy and to society. The paper also explores the notion of strategic foresight, which allows to appreciate the value of innovative approaches in food. Second, the paper looks at Structur3d, a Canadian-based start-up, and how its work reflects the innovations of the larger scale of the global and global economy. Finally, it looks at why 3D printing matters in considerations of food innovation (specifically, in consumption and packaging).

2 Methodology

We chose an exploratory case study design to guide our investigation based on Yin's (1994) argument that case studies are the preferred strategy when 'how' or 'why' questions are being posed and when the focus is on a modern phenomenon within a real-life context. In our study research data was collected through multiple approaches. A semi-structured questionnaire was designed and adopted to collect primary data. The objective of the empirical segment is not to test the applicability of the existing approaches, but rather to study conceptual nuances related to the presented model.

The theoretical basis of the analysis is strategic foresight and innovation management. A survey study focused on formal interviews with executives from Structur3D in Kitchener-Waterloo, in February 2016. Comments were recorded comprehensively for supporting analysis. Respondents were interviewed as key informants in a variety of functional areas, including the President of Structur3D. These individuals possessed sufficient experience and understanding of the organization's culture and strategic intents to be able to comment with authority on the history of Structur3D and knowledge of the 3D food printing market. The interview questions were largely designed to be open-ended in order to provide flexibility in interview discussions. The interviews provided information on the perceptions, application and experience of strategy in licensing. The collected data was arranged, analyzed, and put into the subsequent application phase. A draft version of the paper was submitted for review to the Structur3D for internal validity (Yin, 1994).

3 Strategic Foresight, Scenarios and Knowledge Transfer for Food Innovation

To frame this case study methodologically, we posit that the theoretical developments behind Strategic Foresight, provide a conceptual infrastructure to examine the prospects, opportunities, and challenges that 3D food printing can provide, via knowledge transfer, to manufacturing at large, and to food processing in a global innovation economy. Strategic foresight takes the principle of scenarios as a mental modeling system to help organizations, enterprises, and individuals to seek insight and awareness in their role in an evolving ecosystem and assess how their strategies and choices matter. Scenario models serve to develop tools for tapping into potential future worlds (Ringland, 2010). Crucial to the premise of using strategic foresight to examine 3D food printing is how manufacturing may be disrupted significantly in the coming decades. Strategic foresight's value lies in its ability to enable industries to recognize and respond to changing environments. It is a method to build capacity for future scenario planning (Paliokaite, Pacesa, Sarpong, 2014).

Strategic foresight takes an organization (public or private) as the vehicle for action. In this case, the issue is how it can help the food industry create innovative, sustainable futures with 3D food printing. Strategic foresight provides the tools to shape 'sense-making' in business process and planning (Sarpong, McLean, 2014). Using the theory in the context of 3D food printing is all the timelier by phrasing its methodology as a 'wayfinding' process of practical application, to continually modify strategic business direction. This is more relevant in a sector as prone to disruption and innovation driven as 3D printing (Sarpong et al, 2013).

Strategic foresight examines innovation economics and its business strategy-policy interface through scenario planning with foresight activities aimed at anticipating future societal directions to provide support in current decision making. Konnola et al (2011) set a strategic foresight framework with key design dimensions related to process and outcome to characterise different kinds of foresight projects. The framework applies empirically-based analysis of projects to clarify different roles for foresight in the innovation process, and its respective impact and implications on policy.

For example, one can explore how might patent laws impact the usability of low-cost printers for SMEs entering the 3D food printing space.

To ensure long-term relevance, 3D food printing companies will need to foster the ability to explore, plan, develop and adapt their new business applications (Charlebois, Sterne and Buhr, 2014). Their approach will be challenged in several respects. In response, it would need to integrate multiple perspectives and ensure participation of major stakeholders and decision-makers. In addition, it would need to operate under uncertainty, and account for influencing factors in the food industry (Heger & Rohrbeck, 2012). Multiple perspectives will influence the prospective future development of 3D food printing.

Advanced consideration of potential new opportunities and threats allow business decision-makers to act strategically to maximize benefits or minimize costs. Strategic foresight scenarios are used by governments and business for long-term strategic planning and capacity building. Cook et al (2014) highlights scenario thinking that can be translated for 3D food printing to include the following: monitoring existing problems (consumer trust in food safety); highlighting emerging threats (competition from other 3D printing companies or conventional food processors); identifying promising new opportunities (markets for various demographics and branding applications); testing the resilience of policies (government support programs), and defining an updated research agenda.

Strategic foresight integrates concepts and insights to address future scenarios. It is future oriented and allows multiple stakeholders to plan and negotiate a desirable outcome. Creative thinking is required to facilitate exercises in complex systems, and in a context relevant for applications within an emerging technological application such as 3D food printing (Rasmussen et al, 2010). Our case study of Structur3D examines the broader context in which 3D food printing operates, to explore how innovation processes, facilitated by strategic foresight, exist in a network of proponents, experts, and implementers. A community of practitioners such as 3D food printing companies and their support community need to orchestrate their action to accomplish innovative objectives (Klerkx & Arts, 2013). Strategic foresight can be that point of knowledge transfer that leads to innovative application in 3D food printing. Integrating knowledge transfer has sometimes been referred to as (K*), which is the collective term for the set of functions and processes at the interface between knowledge, strategy, business practice and application. With SF, we improve the knowledge process to bring more effective change to the 3D food printing ecosystem (Shaxson et al, 2012).

With strategic foresight, we can clearly ask: what are the challenges facing Structur3D in terms of an innovation network, and applications in food innovation, and we can examine how knowledge transfer may or may not be effectively facilitated in the Canadian 3D food printing context. Is there knowledge on how to share appropriate forms of knowledge? Are the potential disruptive elements of 3D food printing so value-laden, politicized, and competitive that application at the policy level remains unrealized?

4 Structur 3d

Structur3D has its origins in 2013, when current CEO Charles Mire attended a K-W area 'Maker' event where co-founder Andrew Finkle was presenting his doctoral research on material science applications. The two developed a quick rapport from their shared common language. Mire was a recent PhD graduate, while Finkle was completing his. When the opportunity presented itself for the pair to apply for start-up seed capital funding, Mire approached Finkle to partner on the initiative. With their success from initial program support, Structur3D came to be; they subsequently established a logo, a branding strategy, and an on-line presence. In the fall of that same year, with advice from Mire's mentor, the two applied to Kitchener's Communitech Hyperdrive program. The team had gained significant experience working with applied materials, chemistry, physics and applications in fluid mechanics, both in Canada and internationally. With a successful entry into the Hyperdrive program, their 'Discovery' extrusion systems was recognized for its focus on allowing users to expand the range of fluid materials available for home, hobby, and small business use.

> *"For the Hyperdrive judges, our sample tray was crucial to our success. We had products from 5 materials, including those made from silicone and royal icing. When one of the judges asked about the range of material options available, I explained that we were both fluid material scientists. This gave them further confidence in our business model."*

In the evolving world of 3D printing, material options will continue to be an important business equation, especially considering licensing costs associated with printing, materials and services (Aznar et al., 2015). These options also bring attention to the position of Structur3D within the competing aspects of open source innovation vs. closed source or intellectual property-led innovation. Global leading 3D printing companies such as Stratasys and 3D systems earn revenue not only from their printers, but also from the services and materials that they supply (Vicari, 2014). Competition dynamics have compelled market leaders to secure patent and operating barriers to challenge new player entry. Alternately, open source research labs formulate materials and reduce their costs to allow for lower-end printers greater access to a larger audience (Vicari, 2014). This dynamic between public and open access vs. private intellectual property and patent law will likely continue to be an important debate, which will include 3D printing and food science.

> *"During our ideation and validation process, we asked ourselves to tune into customers who would be like us. We wanted a product where the user did not need to stick with one thing, but rather could try all types of materials, so food was one of them. Royal icing is a sculptable product. While there are professional cake decorators, a specific cartoon character or logo would need a tool like ours. There are however licensing restrictions, if for example, I want a Batman logo on a cake, but now you can download logos from the Internet and personalize the product. Customization is key to our product."*

3D printing can also augment the capacity of existing industries. For established food manufacturers, for instance, the continual demand for new product development can be met with 3D printing (Basiliere, 2014). New research and development can complement existing food innovation opportunities, and home enterprises and SMEs will have an opportunity to use 3D food printing to facilitate prototyping and product development.

A major driving force for the prospects of 3D food printing is in 'mass customization' (ibid, 2014). In this area will be opportunities to create unique, individual products by and for customers, for the restaurant, hospitality and event communities. Marketing, branding and business models will also be potentially invigorated (Charlebois and Mackay, 2010). It is understood that an ongoing challenge will be access to food materials that are safe and able to be prototyped, modelled, and built. Food safety, and how we mitigate risk, in this emergent industry are fundamental issues the industry will need to address (Charlebois, 2011).

Crompton (IBISWorld, 2015) suggests that there will be a significant amount of M&A as manufacturing's largest operators acquire smaller players' technologies. This dynamic might evolve in terms of cost structures as well. While some 3D printers are very expensive and provide the precision and speed needed for more specialty products, on the other end of the spectrum some 3D printers are clearly oriented for hobbyists and home entrepreneurs.

5 Innovation, Information and Disruption Economies

3D printing (or additive manufacturing), has been a process in development for over 30 years. It allows for three-dimensional objects to be printed from digital data (Grynol, 2015). One of the most remarkable advantages of this technology is the ability to iterate and revise products, in turn saving on costly processes more rapidly. Market sales of 3D printers are increasing in a range of industrial and consumer applications, especially transportation, health and packaged goods, including food.

Specifically, 3D food printing is at the forefront of a new means, facilitated by the internet, of open-source innovation. Networks of 'Makers' (a colloquial term for users of 3DP technology) can share, prototype, build and create unique products with reduced overhead. In terms of disruptive economics, 3D food printing requires specialized knowledge of the computer applications, but without incurring the costs of tools, extensive machinery, or molds.

> *"Makers explore and customize, they are scientists and are compelled to do it. We figured this is our market study. We would bring 1000s of materials to the extrusion process with no DRM (digital rights management). With many 3DP companies, the licensing restrictions are a turn-off for the end consumer. Rather people want an open system, and Makers want control. With Structur3d, you can make your product at home, it can become a home business, and the user wants freedom to choose the supply of their materials."*

Structur3D is designed to provide users the freedom to apply different materials with the same extruder product, marketed as the 'Discov3ry' system. As proponents of an open source system for the 'Maker' community, Structur3D see 3D printing as primarily for hobbyists, but also as a natural extension of small businesses. In turn, SMEs can have the freedom to work with various material supplies in their material extrusion process. Structur3D positions its business model counter to the licensing issues with other 3DP companies, and expresses a desire to keep their product as open to using materials and applications in an open source format, while conscious of the growing, competitive world of 3D printing and associated patent laws (Jia, Mustafee and Hao, 2016).

From a strategic foresight perspective, it will be important to consider how applications of 3D food printing might become economically disruptive as well as an opportunity for new business development. Weller, et al (2015) consider the implications of 3D printing on consumer demand for customized product development. Kietzman et al (2015) takes the disruptive capacities of 3D printing further by considering the implications for regulators, policy-makers, intellectual property and business ethics. In the specific context of the Canadian food processing ecosystem, competition and innovation need to be jointly considered.

6 Open Source, Mass Customization and Brand Difference in a Segmented Marketplace

One of the most distinct advantages of 3D food printing is the feature of user customization. In contrast to standardized production, consumers have personalized preferences met. In 3DP in general, we see a human-centred approach to design-led innovation (Mertz, 2013; Banks, 2013).

> *"Our focus market segment was on 'Makers', especially strong in the USA. Makers are often but not exclusively hobbyists. More than that because they put a lot of passion, and detail into their products. They want original things. Makers bring a design mentality, and it extends to their companies, and to those they support. They want to stand out with things that are distinct. They think what their intellectual property is. If they manufacture a vase, it can't look ordinary. If I am an artist, I want something that looks unique with some style. This dazzles them, and they will pay $500 for something that is beautiful. Consumer satisfaction, that is where 'makers' fit in. They want to add some color to life, and our extruder can be one of those tools".*

Seguy (2016) promotes the unique moment in embracing the customization opportunities with 3D food printing that include open innovation and social responsibility. His faith is in the capacity of cloud computing and big data to have computational power influence on the demand for customization in user experience, with the assumption that this will also be more sustainable and provide further impetus towards changing food production systems (Seguy, 2016).

Specific to Structur3D and their associates, they have extruded fluid edibles such as Nutella, hummus, dough, and marzipan. An important evolution in the technology will involve paring food science with curing times, producing evidence that gives 3D food printing its shaping capacity.

> *"With regards to food specifics, we are expanding with materials. We know those who print anything edible that is extrudable. Nutella is ready to go because it has palm oil. The future might have dough made with cricket flour, so you get two points and you bring in publicity. We will need to better understand food drying and curing times. You need to know what works with time, there will be a learning curve"*

Structur3D can apply their extrusion system to the catering, hospitality and restaurant industries:

> *"In our business where trays of food are presented, of course we consider the fact that people don't want to be waiting hungry at a wedding saying, 'Aww jeez, the 3D printer is broken', but you can have complimentary treats at events, where for example, a customized cookie is waiting between meals."*

This application is becoming a reality with market leader 3D Systems, having developed a Culinary Lab at their Los Angeles studio, which partners with chefs and food designers to bring 3D food printing to reality. The limits of food science application and practicality are part of the strategic and creative thinking leading this innovation. For example, Structur3D have considered application within the pet food industry:

> *"There might be the option to use food scraps to make dog treats. Does the dog care about the fancy design, not sure, but people are passionate about their dogs."*

Alternately, a specific 3D food printing niche market may develop for the elderly. Making edible foods that are visually appetizing and nutritious may dramatically change the food pleasure equation for senior demographics on restricted diets (Nasser et al., 2011). Mire adds that a researcher in Waterloo is interested in this prospect:

> *"We have one client who wants to print food for the elderly, because they can't digest solids, but want to make the meal look appealing."*

With equally strong innovative dynamics driving the 3DP and food science frontier, customization as a distinct marketing and branding strategy are giving the prospects for 3D food printing a real opportunity.

7 The Sustainability Imperative, 3D food printing and the Circular Economy

One element to our examination of 3D food printing and Structur3D is to take a closer look at its relationship to broader objectives of environmental sustainability, and what is being linked closely to material science associated with food processing. In 2016, the Ellen MacArthur Foundation, McKinsey & Co, and the World Economic Forum (WEF) released a report entitled the 'New Plastics Economy: Rethinking the Future of Plastics'. In connection to the report, 3D food printing can play an important role in vitalizing the circular economy drive by redesigning material and resource collaboration across the food value chain (Lipton et al., 2015; WEF et al, 2016).

A significant amount of foods is sold as CPG (Consumer Packaged Goods) with a first-use cycle. According to a WEF study, “95% of plastic packaging material value, or USD 80-120 billion annually is lost, with 32% of plastic packaging escaping collection systems, generating significant costs by reducing productivity of natural systems, oceans and clogging infrastructure. In addition, the combined GHG emissions are massive.” (WEF et al, 2016).

One element to the 3D food printing opportunity is the sustainability imperative driven by growing consumer demand, along with greater accounting of packaging material flows. The authors of the study posit that over 2.6 trillion USD annually of consumer goods find their way to the world's landfills and incineration plants (WEF et al, 2016). Yet, we also realize the value of food packaging, reducing food waste, extending shelf life, and reducing package weight (Charlebois, Creedy and von Massow, 2015).

The prospects for 3D food printing might truly emerge as a disruptive alternative to the “over 90% of plastics produced from virgin fossil feedstocks, which represents about 6% of global oil consumption” (WEF et al, 2016). If 3D food printing packaging can adopt innovative material supplies from recycled plastics, this would provide a unique market advantage, but would require strategic planning for innovative policies at the industrial level, and will no doubt pose a disruptive alternative to existing processing systems. Embedded industries benefit from the low-cost, versatility, durability, and high strength-to-weight ratio of plastics as the workhorse material of modern trade economies. The use of plastics has increased twenty-fold in the past 50 years and is expected to double again towards mid-century (WEF et al, 2016).

Plastics in food packaging will also be under pressure with increasing correlations drawn between health risks and volatile compounds including BPAs, phthalates, and PVCs. Some food companies and governments are acting in response, utilizing the opportunity to differentiate themselves, 3D food printing can emerge as a leader in sustainable branding of recycled, food safe, and green packaging.

Additionally, the less predictable costs of the plastics supply chain, linked to fossil feedstock, may put existing food packaging systems at risk, along with the added pressure from regulators.

New forms of plastics recycling, facilitated by material science and design, separation technologies, bioplastics, 3D processing technology and food science can serve as a strategic future action plan (WEF et al, 2016).

3D printing companies can engage with initiatives such as the Consumer Goods Forum "to investigate and promote fundamental redesign" of food packaging materials and formats, and align across the value chain with producers, brands, retailers and after-use collection and reprocessing to change the sustainability and life cycle of food packaged goods (WEF et al, 2016).

In an assessment of 3D printing sustainability at the global level, Gebler et al (2014) consider the relatively new prospects of this technology as a stimulant for sustainable development from lifecycle, energy and GHG emissions perspectives. From an energy impact perspective, 3DP has prospectively lowered input costs and energy needs. If scaled over time, it can fundamentally change labour dynamics towards digitized, customized, and more localized production chains (Gebler et al, 2014). These are all fundamentally important considerations for the food industry. In essence, 3D food printing could find itself at the strategic forefront of industrial metabolism in the production of food fundamental to human existence. 3D food printing can have the added benefit of realizing complex, freeform products not "constrained by the technological limitations of conventional manufacturing processes" (Gebler et al, 2016). In a positive light, 3D food printing is most immediately manifest in the world of CPG, a market worth 100-300 billion USD, and can serve to restructure its supply chains towards more digitized and localized processes (Gebler et al, 2014).

8 Food Processing Futures: 3D food printing & Canada in a Global Innovation Economy

We have outlined elements that are leading the ongoing emergence of 3D food printing in a global innovation economy. In this section, we seek to understand what is happening at the macroeconomic scale, which is driving 3DP technology to evolve internationally as well as in Canada. Leading studies by the Mowat Centre at the University of Toronto, the Ivey Business School and the Lawrence Centre at Western University and the Canadian Agri-Food Policy Institute provide an informed framework to give greater context. Within this context we want to consider how the emergence of Structur3D as a business came out of the applied technology ecosystem at Communitech in the Kitchener-Waterloo region, and how it has developed a unique role to serve in creative contributions to the evolution of 3D food printing.

3D printing, and more specifically, 3D food printing, have the potential to fundamentally change the dynamics of production and manufacturing globally and in Canada. Gress & Kalafsky (2015) consider the location specific implications for this in terms of labour and material supply, consumer demand, global supply chains, pricing competition, and the role of government policy and business innovation strategy. Within a global perspective, Canadian companies such as Structur3D provide an innovative technological niche in the marketplace:

> "*We have strong demand internationally for our product. We have sold to countries around the world, including South Africa, Russia, the UK, Singapore, South Korea, Japan, India, China, the Netherlands, Denmark, Switzerland, Norway, Austria, really world-wide. We also sell well into the researcher market*."

From an economic perspective, food manufacturing in Canada is the largest employer, exceeding the transportation sector (Charlebois and Labrecque, 2009). For its part, 3D food printing might have a unique impact on employment in the sector, including trading prospects, foreign competition, retail concentration, and the potential to change pricing and operating costs. Overall, the agri-food sector in Canada has limited real domestic growth potential, often linked to demographic leveling (Sparling & Cheney, 2014). Investment in new innovations enabled by 3D food printing might emerge as a new strategic advantage.

Boothe & Dicerni (2014) consider how government policies and programs provide the vital support to facilitate development and capacity for emerging technologies such as 3D food printing. Given that value-added manufacturing provides the advantage to jurisdictions in the global innovation marketplace, we consider how Canada compares to its peers in technological development support across the 3D food printing spectrum, and specifically to the case of Structur3D.

Both the Mowat Centre at the University of Toronto and the Lawrence Centre at Western University have assessed Ontario's specific challenges in becoming a leading manufacturing region, and some of the most relevant opportunities within applied technology. Close monitoring of industrial structure, plant capacities and technologies support programs for start-ups and emergent sectors, the investment community and the state of innovation are directly required (Mowat Research #83, 2014; Sparling et al, 2014).

Competitive market forces are driving food manufacturers towards greater automation. 3D food printing serves the demand for automation, especially with larger processors, but also mass customization with makers, hobbyists, and small and medium sized businesses, as in the case of Structur3D. In Canada, companies with less than 50 employees make up 80% of the food processing industry, but account for only 17% of profits (Sparling et al, 2014). Leading Canadian food processors such as Maple Leaf, Saputo and Richardson International are investing heavily in machinery, robotics and automation (Charlebois and Giberson, 2010).

The irony is that automation reduces labour costs in the food industry; in a recent report, however, food executives wondered where the skilled workers will come from to run the more sophisticated production automation equipment (Sparling & Cheney, 2014). It also remains to be seen whether the move towards automation and robotics will be able to create significant new jobs.

In the past decade, according to Oschinsky, Chan and Kobrinsky (2014), Canada alone has lost over 300,000 manufacturing jobs. In their study for the Mowat Centre, they outline the implications of the global value chain, where sections in the development of a product are designed, marketed, manufactured, and assembled in different regions of the world. New processes and logistics systems are revolutionizing global manufacturing. Innovation, manifest in many forms, is essential to survival, especially for small and medium size businesses. In this context, policy and programs are critical. Compared to its OECD peers, Canada since 2000 has been dropping its R&D investment spending per capita (Dooner, 2014).

More recently, Quebec has taken an activist approach to fostering a productive food manufacturing sector that attracts investment. In the case of PepsiCo, the company moved a Frito-Lay plant to Quebec City because of government commitment to prioritize logistics in supplying potatoes to its processing plant (Juhasz & Charlebois, 2015). In western Canada, the Alberta government's Agri-business Automation and Lean Manufacturing Fund covers up to 50% of process innovation, automation, improvement, and adaptation.

In a 2014 Canadian Manufacturers & Exporters Management Issues survey, high priority issues for processors identified federal initiatives such as the Scientific Research and Experimental Development (SR&ED) program to focus on process and product invention and improvement. Such programs and broader macro-economic trends as “re-shoring” in North America are part of what can lead to 3DP being a choice for greater efficiency, consumer responsiveness and innovative quality control. Leading-edge food processing research can apply advanced robotics to allow SMEs to compete strategically (Juhasz & Charlebois, 2015). Additionally, the Canadian Accelerated Capital Cost Allowance Program facilitates the duty-free import of equipment to advance manufacturing.

In Southwestern Ontario, creative synergies are underway in clusters such as the Canadian Technology for Food Initiative at the Accelerator Centre in Waterloo region. The initiative is focused on strategic development in the food manufacturing sector across the value chain. With Kitchener-Waterloo's IT strengths that include Communitech, the University of Waterloo, the Craig Richardson Institute for Food Processing Technology at Conestoga College in Cambridge and the agri-food sciences ecosystem around the University of Guelph, the region can potentially serve as a world-class destination for innovation (Juhasz & Charlebois, 2015).

The benefit that value-added manufacturing provides to economies is significant, so competition to attract and retain companies is intense. Staying competitive will require ongoing investment in new technologies, processes and systems, of which 3D food printing can be an important part. Companies operating in food manufacturing will need to focus on improving capacity in two key areas: first, on innovation in product design and the processes used to make them, and second, efficiency in planning production and managing purchasing and labour costs (Boothe & Dicerni, 2014).

Amid innovation economics and the forces of standardization or differentiation, off-shoring or re-shoring, SMEs or global competitors, one alternate path that Structur3D can navigate is to consider the job-creating space of mass customization and differentiation, even while the path may not be as revenue rich:

> *"We know that large manufacturers are using automation, such as with frozen pizza. Ultimately our business model can one day potentially offer food loaded cartridges, that are filled and ready to go, but we would need FDA/CFIA approval to make it food safe*"

Mire retains faith in the market for customized food experiences, either at restaurants, special branding and marketing events, through catering and hospitality, or at weddings, the uniqueness of 3D food printing has its advantage:

> *"Some food manufacturers use million dollar machines, produce en mass and they have to for markets. Generally lower cost 3DP is not this fast. Extruded 3D pizza might not be so appetizing, but if you are doing a party, you want to have design. You can do the marketing and have visualization of your food. You are getting a customized dish, a unique experience, you will eat these things as a rare treat."*

While Mire contests that the market is still determining the 'killer applications' for using 3DP in the food space, there may very well be a range of applications.

9 Conclusion

We have outlined in this study how 3D printing is increasingly emerging as a disruptive technology demanding to be recognized for its potential contribution to a rapidly evolving innovation economy here in Canada, and internationally. By extension, 3D food printing will have equally profound impact on food science, health, sustainability, and what we consider possible in food cultures and economies.

Consumer behaviours, expectations, buying habits, and biases will drive incentive for 3D food printing and serve as a challenge to build trust or possibility. The 3D printing world exists along a spectrum, from advocates and users of open-source materials and applications operating in a spirit of sharing, creativity and craft, to those who see large-scale applications of 3D printing to meet pressing industrial, health, and transportation needs, and who are likely to press for ongoing patent laws and intellectual property protection of their research and development investments. The grey scale in-between is undoubtedly wide.

Some applications in 3D food printing might very well be fads and forms of novelty, while others may have real, lasting value in a new sustainability economy. In the growing call for a circular economy that considers the profound environmental impact of products, and the materials used, 3D food printing can take strategic centre in helping to make these initiatives more tangible and price competitive. Companies such as Structur3D can be a vitally important part of this innovative evolution. How we navigate this space at the sub-national jurisdictional level, nationally, and through international trade economics will be determined in part by users, the drive of customization, environmental regulations, food consumption trends, and innovation policy. Strategic foresight as a scenario tool can help us ask better questions, plan, and then to act collectively, and at the business level.

Acknowledgements

The authors want to thank the Food Institute, and the Food & Agriculture Business Seminar in supporting the development of this study. We also thank Charles Mire, CEO of Structur3d, for the interview.

References

Aznar, Domeño, Nerín, and Bosetti (2015). Set-off of non-volatile compounds from printing inks in food packaging materials and the role of lacquers to avoid migration. *Dyes and Pigments*, **114**: 85-92.

Banks, J. (2013). Adding Value in Additive Manufacturing. Nov/Dec 2013: 22-27, IEEE Pulse.

Basiliere, P. (2014). Market guide for 3D Printing, Gartner.

Boothe, P., Dicerni, R. (2014). The Future of Canadian Manufacturing: Learning from Leading Firms: Public Policies to Support Advanced Manufacturing, Ivey Business School - Lawrence National Centre for Policy and Management.

Charlebois, S., Labrecque, J. (2009). Sociopolitical foundations of food safety regulation and the governance of global agrifood systems. *Journal of Macromarketing*, ***29***(4): 363-373.

Charlebois, S. (2011). Food recalls, systemic causal factors and managerial implications. *British Food Journal*, **113**(5): 625-636.

Charlebois, S., Mackay, G. (2010). Marketing culture through locally-grown products: The case of the fransaskoisie terroir products. *Problems and Perspectives in Management*, ***8***(4): 91-102.

Charlebois, S., Giberson, R. (2010). From classroom to boardroom: How international marketing students earn their way to experiential learning opportunities, and the case of the" beyond borders of a classroom" program. *Marketing Education Review*, **20**(2): 163-172.

Charlebois, S., Sterne, R., and Buhr, M. (2014). Sharing and preparing: Cross-institutional, food security-based knowledge in Canada. *International Journal of Sustainable Development & World Ecology*, **21**(6): 532-539.

Cook, C.N. et al., (2014). SF: How planning for the unpredictable can improve environmental decision-making. *Trends in Ecology & Evolution*, **29(**9): 531-532.

Charlebois, S., Creedy, A., and von Massow, M. (2015). “Back of house”–focused study on food waste in fine dining: the case of Delish restaurants. *International Journal of Culture, Tourism and Hospitality Research*, **9**(3): 278-291.

Crompton, J. (2015). IBISWorld Industry Report - OD44238 - 3D Printer Manufacturing in the US, January 2015.

Dooner, A. (2014). Canadian Manufacturing in a Global Context, Ivey: Lawrence National Centre for Policy and Management, 2014

Gebler, M., Schoot-Uiterkamp, A.J.M., Visser, C. (2014). A global sustainability perspective on 3D printing technologies*.* *Energy Policy*, **74**: 158-167.

Gress, D. R., Kalafsky, R.V. (2015). Geographies of production in 3D: Theoretical and research implications stemming from additive manufacturing. *Geoforum*, **60**: 43-52

Grynol, Benjamin. (2015). Disruptive manufacturing: The effects of 3D Printing, Deloitte.

Heger, T., Rohrbeck, R. (2012). SF for collaborative exploration of new business fields. *Technological Forecasting & Social Change,* **79**: 819-831.

Jia, F., Wang, X., Mustafee, N., and Hao, L. (2016). Investigating the feasibility of supply chain-centric business models in 3D chocolate printing: A simulation study. *Technological Forecasting and Social Change*, **102**: 202.

Juhasz, M., Charlebois, S. (2015). Canadian Agri-Food Manufacturing Investment Case, Department of Foreign Affairs, Trade & Development Canada.

Klerkx, L., Arts, N. (2013). The interaction of multiple champions in orchestrating innovation networks: Conflicts and complementarities. *Technovation*, **33**: 193-210.

Kietzmann, J., Pitt, L., Berthon, P. (2015). Disruptions, decisions, and destinations: Enter the age of 3-D printing and AM. *Business Horizons*, **58**: 209-215.

Konnola, T., Scapolo, F., Desruelle, P., Mu, R. (2011). Foresight tackling societal challenges: Impacts and implications on policy-making. *Futures*, **43**:252-264.

Lin, C. (2015). 3D Food Printing: A Taste of the Future. *Journal of Food Science Education*, **14**(3): 86-87.

Lipton, Cutler, Nigl, Cohen, and Lipson. (2015). Additive manufacturing for the food industry. *Trends in Food Science & Technology*, 4**3**(1), 114-123.

Mertz, L. (2013)Dream It, Design It, Print It in 3-D. Nov/Dec. 2013, IEEE Pulse: 15-21.

Mowat Research (2014). Ontario Made: Rethinking Manufacturing in the 21st Century - Summary Report. Mowat Centre, # 83. Feb 2014

Nasser, R., Cook, S., Bashutski, M., Hill, K., Norton, D., Coleman, J., and Charlebois, S. (2011). Consumer perceptions of trans fats in 2009 show awareness of negative effects but limited concern regarding use in snack foods. *Applied Physiology, Nutrition, and Metabolism*, **36**(4): 526-532.

Oschinsky, M., Chan., K., Kobrinsky, L. (2014). Ontario Made: Rethinking Manufacturing in the 21st Century, Mowat Centre.

Paliokaite, A., Pacesa., N., Sarpong, D. (2014). Conceptualizing Strategic Foresight: An Integrated Framework. *Strategic Change*, **23**:161-169.

Rasmussen, B., Andersen, P.D., Borch, K. (2010).. Managing Transdisciplinarity in: *Strategic Foresight*, Vol **19**: 1

Ringland, G. (2010). The role of scenarios in SF. Technological Forecasting & Social Change. 77: 1493-1498.

Sarpong, D., Maclean, M. (2014). Unpacking SF: A practice approach. *Scandinavian Journal of Management*, **30**: 16-26.

Sarpong, D., Maclean., M., Alexander, E. (2013). Organizing SF: A contextual practice of 'way finding'. *Futures*, **53**: 33-41.

Seguy, S.I.. (2016). Challenges and opportunities in food engineering: Modeling, virtualization, open innovation, and social responsibility. *Journal of Food Engineering*, **176**: 2-8.

Shaxson, L., Bielak, A.T., et al. (2012). Expanding our understanding of K* (KT, KE, KTT, KMb, KB, KM, etc.) A concept paper emerging from the K* conference held in Hamilton, Ontario, Canada. April 2012. UNU-INWEH, Hamilton, ON.

Sparling, D., Cheney, E., LeGrow, S. (2014). The Future of Canadian Manufacturing: Learning from Leading Firms - Canadian Food Manufacturing, Ivey Business School: Lawrence National Centre for Policy and Management.

Sparling, D., Cheney, E. (2014). The Performance of Canada's Food Manufacturing Industry. CAPI Processed Food Research Program: Project 3a, CAPI.

Sun, J., Zhou, W., Huang, D., Fuh, J., and Hong, Y. (2015). An Overview of 3D Printing Technologies for Food Fabrication. *Food and Bioprocess Technology*, **8**(8): 1605-1615.

Vicari, A. (2014). How 3DP adds up: emerging materials, processes, applications and business models, March 2014, LuxResearch

Vicari, A., Kozarski, R. (2013).. Building the Future: Assessing 3D Printing's Opportunities and Challenges, LuxResearch, March 2013.

Weller, C., Kleer., R., Piller, F.T. (2015). Economic implications of 3D printing: Market structure models in light of additive manufacturing (AM) revisited. *Int. J. Production Economics*, **164**: 43-56.

World Economic Forum (2016). Ellen MacArthur Foundation and McKinsey & Co. The New Plastics Economy: Rethinking the Future of Plastics, 2016.

Yin, R. K. (1994). Discovering the future of the case study. Method in evaluation research. *Evaluation practice*, **15**(3): 283-290.