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Investigating the feasibility of supply chain-centric business models in 3D chocolate printing: A simulation study

Fu Jia [a,b], Xiaofeng Wang [c,*], Navonil Mustafee [a], Liang Hao [d]

[a] Business school, University of Exeter, UK
[b] School of Economics and Management, Minjiang University, Fuzhou, China
[c] Glorious Sun School of Business and Management, Donghua University, Shanghai, China
[d] Advanced Materials and Manufacturing School, University of Exeter, UK

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ABSTRACT

3D chocolate printing provides the technology for manufacturing chocolates layer-by-layer, thus offering customers enhanced product value and personalized consumption experience. As business models in the chocolate industry are closely associated with the profitability of the supply chain constituents, it seems appropriate to investigate the financial viability of these supply-chain centric business models prior to their introduction in the real world. In this paper we present two business models pertaining to the supply chain for 3D printed chocolates; we evaluate the financial viability of these innovative models through the use of computer modelling and simulation. The study is based on the commercialization efforts of a UK based 3D chocolate printing technology provider (Choc Edge). The results of the study indicate that 1) the retailer dominant supply chain model is a potentially disruptive business model innovations that are enabled by the 3D food printing technology, and as such, may pose a challenge to traditional high end chocolate products; 2) the manufacturer dominant model helps manufacturers gain more profits while retailer profits tend to be stagnant.

1. Introduction

Traditional chocolate manufacturers such as Dove, Cadbury, Hershey and Ferrero, capture the most market shares of the confectionary industry by offering standard chocolate bars and gift boxes. In order to deliver more customer value propositions, there are some small and medium sized chocolate manufacturers such as Chocolate Bouquets directly selling handmade chocolates via e-commerce platforms such as eBay or Amazon. Besides, some upscale chocolate manufacturers such as Teuscher (www.teuscher.com) provide highly customized chocolate products in terms of fruits, spices, nuts, confectionery and white/dark cocoa, which allows for more than 27 billion combinations (www.createmychocolate.com). Although the launch of customized chocolate products fulfil the increasing requirements for personalization, the mainstream chocolate consumers are faced with long order-to-delivery time and prices that are generally 2–3 times higher than traditional chocolate products. As the market requirement for customized chocolate keeps growing, satisfying customization needs at relatively low costs is a challenge that is faced by many players in this industry. The application of 3D printing technology in the chocolate industry is an innovative approach towards mass customization of chocolates.

The prototype 3D chocolate printing technology that was developed at the University of Exeter (BBC News, 2011; BBC News, 2012), represents a revolutionary product innovation and manufacturing approach which can engage consumers to create and produce chocolate gifts locally and share their digitized product design and innovation globally through online communities. Clearly this new technology represents great potential to reconstruct food innovation, production and supply chain in the future, in particular achieving a leagile and low carbon food value chain (Christopher, 2011). However, our search of literature in 3D food printing using bibliographic databases *ISI Web of Knowledge* and *Scopus* retrieved only 6 and 15 articles respectively (the keywords used were *3D food print**, *additive manufacturing*, *rapid manufacturing*, *rapid prototyping*, *solid freeform fabrication*, *layer manufacturing*; search conducted on *article title*, *abstract and keywords*; final search was conducted in December, 2013). Of these, the relevant articles focused primarily on engineering and automation (e.g., Millen et al., 2012) and food science (Kim et al., 2012). There is presently little research carried out to date studying the impact of 3D food printing on the supply chain of innovative food products and their underlying business models; a possible reason for this is that 3D food printing is at its infancy and research in this topic should arguably be preceded by commercialization of this technology and the creation of associated supply chains, both of which are still developing. In the context of 3D chocolate printing, to the best of our knowledge there is only one technology provider attempting to commercialize operations in the UK: *Choc Edge*. The company was founded by a co-

* Corresponding author.
E-mail address: xfwang@dhu.edu.cn (X. Wang).

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author of this paper and the University of Exeter for commercially exploiting 3D chocolate printing (https://chocedge.com/).

Robust business models are necessary for ensuring the economic sustainability of 3D chocolate printing. It should take into account the profitability aspects of the supply chain constituents, viz., the manufacturer and the retailer, and the utility derived by the end user (e.g., permitting both shape and mix customization of chocolate products). Towards this, we present two business models that are being considered by Choc Edge — the *manufacturer-dominant model* and the *retailer-dominant model*. The question now arises as to how we assess the economic sustainability of business models based on supply chain configurations that do not yet exist? This brings us to the next part of the study which has applied *computer simulation* in the context of supply chains (supply chain simulation). A computer simulation is a quantitative technique that uses the power of computers to conduct experiments with models that represent either an existing or a proposed system of interest (Pidd, 2004). In this research we use simulation for modelling the supply chain constituents and their profitability functions with the aim of experimenting financial viability of the proposed manufacturer-dominant and the retailer-dominant model business models. Due to the nascent nature of the 3D food printing technology (Eisenhardt, 1989; Yin, 2003) a simulation case study is an effective experimentation-based approach to evaluate new business model innovations. Such an approach has been used previously in the context of ascertaining the financial viability of business models pertaining to telecommunication networks (Bohlin, 2007).

The contribution of the paper is twofold. First, it outlines two business models for 3D printing of chocolates and compares it to the traditional model for the production of standard chocolates. Second, the paper presents a simulation study to assess the financial viability of the two proposed business models. As discussed earlier in the paper, there is presently no literature on 3D food printing and its effects on existing food supply chains and business models; and thus the novelty of our contribution.

The remainder of the paper is structured as follows. Section 2 presents a literature review on business models in food supply chains. Section 3 then outlines our research methodology which uses computer modelling and simulation. Section 4 is on business models; it discusses them in relation to 3D printing-enabled customized chocolate production (the proposed manufacturer-dominant and retailer-dominant models) and standard chocolate production (*traditional model*). Section 5 presents the simulation logic and the equations that are implemented in the computer model. The simulation results are discussed in section 6. Section 7 presents a discussion on the entrepreneurial challenges faced by Choc Edge as it attempts to commercialize the technology and what adaptations to its business model and strategy might be necessary for it to be commercially successful. Section 8 is the concluding section of the paper.

2. Literature review

Traditional chocolate making is a highly sophisticated process using specialized machinery. The production method may involve moulding (e.g., pouring moulding), enrobing and roll forming (Aasted, 1998; Beckett, 2009), among others. Furthermore, different mouldings require different chocolate production machines and lines (Jeffery et al., 1977). These traditional methods of chocolate production focus primarily on standard products and mass manufacturing (Akutagawa, 1983; Hunter, 1927) and capture the majority of the market share. However, they cannot match customer demands for customized chocolates (Beckett, 2009). Although traditional methods can manufacture such products, they are expensive and time consuming as they frequently necessitate the manufacture of customized moulds (Aasted, 1998).

In this section we present a review of literature on business models in food supply chains (Section 2.1). Robust business models are necessary for ensuring the economic sustainability of chocolate production, taking into account the profitability aspects of the supply chain constituents. In this paper this is referred to as supply chain-centric business model innovations and is further discussed in Section 2.2.

2.1. A review of business models for food supply chains

Food Supply Chains (FSC) are an example of complex supply chains and consist of several inter-dependent steps, for example, farming, food processing, distribution, retailing and consumer handling (van der Vorst, 2000). In between these operations, storage, packaging and transport need special considerations due to food safety issues (Jennings, 2005). As a result of the long process flows and food storage, the logistics costs are high. With regard to FSC for chocolates, the chocolate production processes have strict requirements for temperature control, which pushes the cost even higher (Aasted, 1998). The main challenges of the traditional FSC are how to shorten the food process, reduce logistics and storage costs, and enhance the consumption value of products (Christopher, 2011). Nowadays, supply chain and logistics managers face another challenge and are required to re-evaluate their strategies and tactics to make the food supply chain more sustainable (Flint et al., 2008). The traditional FSC and production lines are more appropriate for mass manufacturing of standard products or for limited customization products; customized products, on the other hand, require expert skills of hand-decoration which are often associated with high labour costs (Berkes et al., 1984).

Customization involves seeing each customer as a potential market segment and designing and producing individualized products, and quickly delivering them to each customer (Fitzgerald, 1995). Boland (2008) illustrated that there are an increasing number of consumers who require personalized nutrition, and they are willing to pay a premium price to buy innovative food (Cohen et al., 2009; Hendry, 2010). Personalized nutrition becomes a mainstream in affluent societies (Boland, 2008), with a goal of healthy lifestyle (Boland, 2008; Martínez et al., 2008). At the same time, customers want to receive products and services with a certain degree of individualization (Gilmore, and Pine, 1997; Franke et al., 2009).

As a result of manufacturers' decisions to configure their products to match every customer's individual preferences, the relationship between manufacturers and customers has been enhanced (Wong and Eyers, 2011; Simonson, 2005). However, the manufacturer's total cost (e.g., production and logistics) would increase linearly with the number of products available to the market (Banerjee and Golhar, 2013). Furthermore, in the midst of fierce competition and diversified product offerings in the market, manufacturers find it difficult to simply expand product ranges, and they do not have enough flexibility to respond to this rapid change in customer demands (Wang, 2011), such as in regards to product designs, colour, sizes and packaging (Childerhouse et al., 2002; Wang, 2011). Therefore, it has become a common trend to continuously improve the level of customization in the FSC for producing standard products in the market (Lyons et al., 2013).

Discussing the impact of the customization on the FSC, Wang (2011) proposes a dynamic model, which states that product customization level would be affected by product costs and potential profit margin, inventory cost of semi-finished products, shortage costs and inventory costs. Echoing Wang (2011); Wong and Eyers (2011) concentrated on several key factors such as the inventory level, number of product variety, price, and delivery lead-time, which may inhibit or promote the use of a higher level of customization. In addition, producing customized products may create solutions for postponement in FSC. For instance, customized production will not start until manufacturers receive a clear order from customer preference (Periard et al., 2007), thus, the issue of delaying or postponing production of a product can be solved (Banerjee and Golhar, 2013; Getschmann, 2013).

Arguably, the FSC factors which inhibit the large scale adoption of personalized food products will also apply to the supply chains for customized chocolates. However, it's possible that impact on the latter may be diminished considering that an innovative food processing technology (like 3D chocolate printing) may simplify logistics and thereby reduce

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