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The article found that the limited use of this valuable technological resource is linked to several factors, mainly cultural, generational and educational. The article exposes two key new technologies that could help the industry reduce its carbon footprint.

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Findings: The article found that the limited use of this valuable technological resource is linked to several factors, mainly cultural, generational and educational. The article exposes two key new technologies that could help the industry reduce its carbon footprint.

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Key words: Big Data; Biotechnologies; Textile industry; Generational conflict; Environment; LMX.

INTRODUCTION

Recent developments in industrial biotechnology offer eco-friendly approaches without compromising production efficiency and product quality in manufacturing. Industrial biotechnology encompasses the use of enzymes and defined microorganisms for goods and services (Dubey et al., 2016; Chen et al. 2016; OECD, 2001; Jørgensen et al., 2006). Therefore, enzymes have seen increasing applications in many industrial processes which resulted in fast growth in the global industrial enzyme market and evolved into a multibillion-dollar business (Sarmiento et al., 2015). Despite the presence of enzymes in all living entities, most of the enzymes used in industry are microbial. Industrial enzymes have applications in different sectors including leather, tanning, textile, pulp and paper, pharmaceutical products, food, detergent, starch industries, and more. (Li et al., 2012; Rahman, Billah and Hack-Polay, 2019; Sarmiento et al., 2015). Approximately 10% of the industrial enzymes account for textile processing (Silva et al., 2010; Choudhury, 2014). Textile fibers and fabrics undergo a number of long production and manufacturing processes before they could be used for preparing garments or apparel. Textile wet preparatory processes, which consist of scouring, bleaching, coloration, and finishing, are carried out in water-based systems and deemed indispensable to improve the performance and utility of textile materials (Kumar and Gunasundari, 2018). Almost all dyes, specialty and finishing chemicals used in textile applications are incorporated into the textile substrates from water bath, through either solution, dispersion or emulsion. In textile wet processing, water serves mainly two purposes (as a medium for handling and using chemicals and as the solvent for washing and rinsing the textile materials). The wet processing of textiles puts a heavy burden on water and energy usage. In addition, textile industries employ various chemicals in processing, from the initial materials to finished products. These chemicals are expensive and pose significant threats to the environment, the ecosystem and aquifers and to manufacturing workers' health (Ripple et al., 2019; Shen and Smith, 2015; Saxena et al., 2017; Kumar and Gunasundari, 2018). This has caused serious concern and necessitated the inclusion of safer and environmentally friendly, green alternatives. Consumers increasingly demand the incorporation of sustainable textile materials and apparel (Gwozdz et al., 2017). Bio-based processing presents significant potential to replace harmful chemicals, require less water and energy, therefore contributing to sustainability (Maiti et al., 2018).

This study's justification centres on the evidence that the textile and clothing industry is a major part of manufacturing and trade in many developing countries. These countries have taken advantage of relative ease of entry into this field and the unusually high labour cost in developed countries have favoured the manufacturing of textile, and apparel products in developing countries (Rahman and Mendy, 2019). Exporting these products benefits the producers in generating income that helps local economies in developing countries, and benefits the consumers in developed countries as they get these products at competitive prices (Mendy and Rahman, 2019). However, due to the loose regulatory frameworks in those developing countries, environmental concerns and degradation are not always duly addressed. Additionally, owing to competition, more stringent ecological parameters and international pressures, it is primordial that textile processors be conscious of ever higher quality and ecological requirements. Biotechnological processes can contribute significantly to eco-friendly manufacturing by replacing traditional textile production systems. With this in mind, this paper sits in the context of current debates about climate emergency increasingly advocated by scientists (Ripple, 2019).

This article seeks to answer the following research questions: What is the scientific argument supporting the effectiveness of biotechnology in textile processing? To what extent can the use of biotechnology, particularly enzyme processing, bring about greener alternatives in textile industries? Why has decision-making regarding the use of biotechnology been slow in the textile industry in developing countries? What role can Big Data play in changing decision-making with regards to adopting biotechnologies? In answering these research questions, the focus of the analysis in this study is on two key biotechnologies in textile: Bio-bleaching and Bio-finishing. This focus is linked to the fact that they are novel and information about them as well as their application are only emerging in the developing world.

Theoretical framework

Decision-making is a complex area. This complexity is compounded by the evolving nature of the contemporary socio-technological environment. This entails that decision-makers are compelled to rely on a variety of decision-making frameworks or models. In the context of this analysis, the view that leaders and organisational members should be collaboratively involved in the decision-making process in order to arrive at greater effectiveness is adopted (Raiffa, Richardson & Metcalfe, 2002; Graen and Uhl-Bien, 1995; Dansereau et al., 1975). Therefore, the Leader-Member-Exchange (LMX) framework is employed to support the argument in this study.

Graen and Uhl-Bien (1995) advocate the necessity to validate differentiated relationships within the organisation since there are various levels of information and knowledge at the various layers in the organisation. They see intricate connections between LMX and organisational outcomes or performance. There is no emphasis on consensus decision-making within the LMX theory. However, the ability of the leader and followers to maintain positive relationships is conducive for a greater understanding of issues, and therefore a plurality of ideas that could enter the decision-making process; thus, leading to more impactful decisions and effective implementations (Nohria and Khurana, 2010; Dansereau et al., 1975). Blockages in the leader-follower relationships lead to deficiencies in suggestions and solutions (Pigg, 2009).

There is evidence that there exists a correlation between LMX and organizational citizenship, retention and trust in the leader, though the correlation was stronger in Western cultures than Asian (Rockstuhl et al. 2012). Additionally, Javed, Khan and Quratulain (2018) found strong evidence that LMX influences the development of innovative work behaviour. In the context of the application of new biotechnologies in the textile industry, LMX theory could lead to an interesting avenue for analysis. Because the industry is largely dominated by older owners who have the means of production, and therefore the decision-making powers, LMX theory presents strong analytical possibilities for several reasons. First, there is the possibility of generational tensions between an older generation of entrepreneurs whose main theoretical stance is founded on the 'economic man" (Dansereau et al., 1975) and a younger generation of workers and managers who are more technology-aware and environment-conscious. Similarly, as we consider the developing world context in this study, the influence of culture cannot be overestimated. In fact, in most Asian cultures, age is an important parameter in terms of who gets to speak first. In this context, elders are thought to have the primacy in decision-making – a different level of rational decision-making (Cabantous and Gond, 2010). The LMX enables us to consider the leader-follower relationships from multiple angles and assists in establishing whether the nature of these relations hinders or supports decisions about the adoption of new environmentally-friendly biotechnologies in the textile industries in the developing world. The conceptual model (Figure 1) shows the possible interrelations between the LMX, management decision and application of big data as fostering sustainability in textile manufacturing.

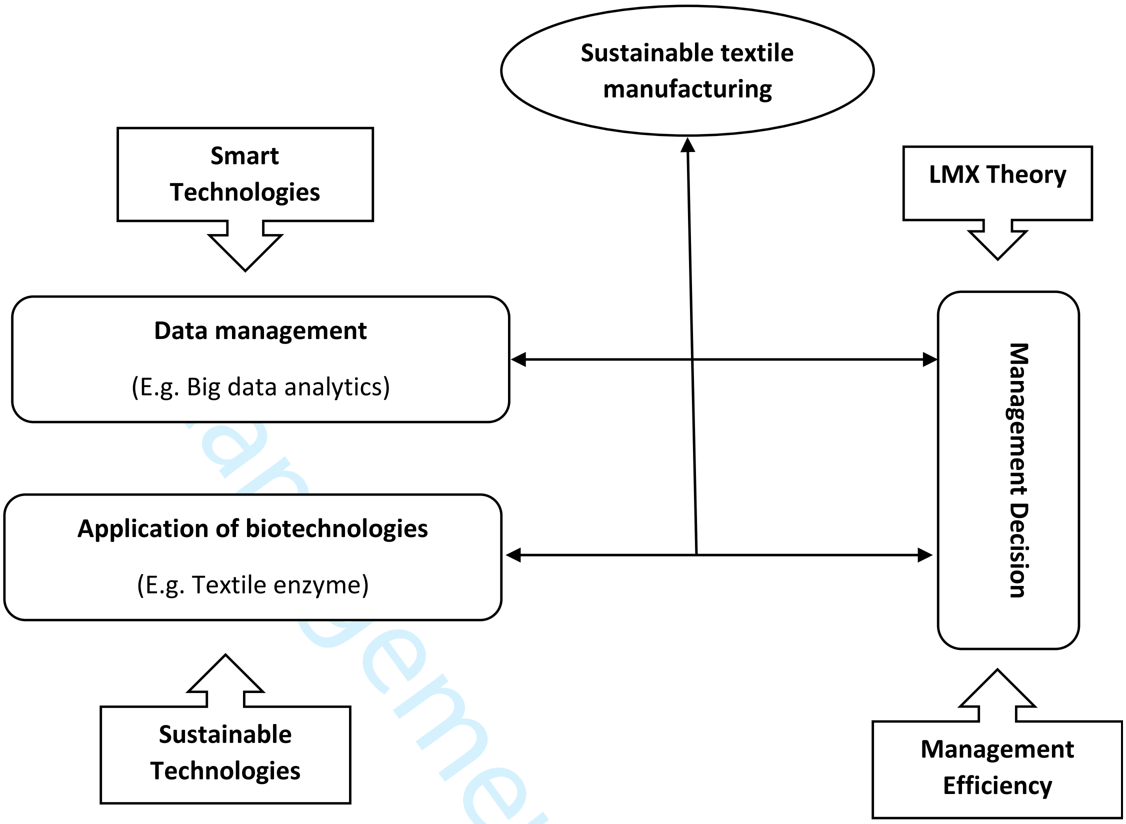

Fig. 1 - Conceptual framework on Sustainable textile manufacturing

According to the above conceptual framework (Figure 1), management decision can play a significant role in the application of big data analytics and biotechnologies for sustainable textile manufacturing. In Figure 1, on one hand, management decision influences the application of big-data and biotechnology. On the other hand, the application of *big*-data and biotechnology can also influence management decision.

METHODOLOGY

The article relies on academic literature to examine the potency of the use of enzymatic processing for environmental sustainability in the textile industry. This departs from "traditional hypothetico-deductive approach" to exploit the potency of secondary data in constructing a critical argument (Dana & Dana, 2005). The hypothetico-deductive approach assumes rationality and the formulation of testable propositions (Albert and Couture, 2014). Ju and Choi (2018) view the PDR as significant framework of problem solving and analysis; however, they maintain that it can be enhanced by integrating what they refer to as a Problem Based Learning (PBL) approach. Our methodological framework adopts this approach because through critical intellectual debate, it is possible to explore 'the causes of a given problem that is complex and ill structured, generate multiple solutions, negotiate alternative solutions' (Ju and Choi, 2018: 12). First, literature is analysed to address the important developments in biotechnology which is geared at resolving some of the negative environmental impact of traditional processing in the textile industry. In doing so, relevant literature that captures and looks into two or more of the following concepts: technology, Big Data and textile and environmental sustainability. This is followed by a discussion of the main studies supporting the use of enzymatic processing and biotechnology, categorizing the benefits but also dialectically establishing the issues associated with the use of biotechnology. This two-way approach expands the consideration of reasonable rival hypotheses, process outlining and counterfactual rational (Dana, 2015) in the debate about the use of biotechnology in view to derive the benefits associated with enzymatic treatment in textile for environmental sustainability in developing countries.

DEVELOPMENTS IN BIOTECHNOLOGY IN THE TEXTILE INDUSTRY

Perspectives on Enzymes in textile wet processing

Enzymes are biological catalysts which are responsible for performing specific chemical reactions. They usually require comparative mild conditions for their operation. All enzymes are proteins in nature and decompose after their lifetime (Shen and Smith, 2015). Some enzymes require specific small non-protein molecules, known as cofactors, in order to function as catalysts. The reaction specificity of the enzymes could be used for targeted textile applications without undesirable effects (Shen, 2009). Commercially, enzymes are usually manufactured by fermentation from three primary sources: animal tissues, plants, and microbes. Enzymes are classified as oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases (Choudhury, 2014). Most enzymes used in textile wet processing are hydrolases, which are responsible for catalyzing hydrolysis of chemical bonds. This group comprises of amylases, cellulases, pectinases, catalases, and proteases, which are used in various textile processing. However, laccases and peroxidases belonging to oxidoreductase group found interesting textile applications which include decolorizing textile effluents, bleaching textiles, modification towards the surface of the fabrics, and synthesis of dyes (Shen and Smith, 2015). Specific enzymes, alone or used in combination of other enzymes for textile applications are shown in Table 1.

Table 1 Application of enzymes in textile processing and their mechanism of actions

Major group of enzyme	Name of specific enzymes	Application in textile processing	Mechanism of actions
Hydrolases	Amylase	Bio-desizing	Breakdown of starch into simpler sugars
	Lipases	Bio-desizing; Detergent formulation	Decomposition of fats and oils into glycerol and fatty acids Removal of lipid stains
	Cellulases	Bio-scouring; Bio-stoning, Bio-finishing, Wool carbonization	Breakdown of cellulose into soluble products
	Pectinases	Bio-scouring	Decomposition of pectin
	Cutinases	Bio-scouring	Hydrolysis of insoluble cutin into cutin monomers
	Xylanases	Bio-bleaching	Degradation of the linear polysaccharide beta-1,4-xylan into xylose
	Proteases	Wool modification	Hydrolysis of peptide bonds of proteins into soluble polypeptides and amino acids
Oxidoreductases	Laccases	Bio-bleaching; Dyeing, Textile effluent decolourisaion	Degradation of recalcitrant organic compounds through catalyzing transfer of electrons from one molecule
	Catalases	Peroxide removal	In situ decomposition of peroxide

New biotechnologies enabled the effective use of these enzymes, which minimize environmental degradation and the effect on the health of people living in the vicinities of processing plants in the developing world. However, decisions as to the adoption of these new technologies is not forthcoming.

Bio-bleaching

Bleaching is considered to be one of the major steps of textile wet processing prior to cotton dyeing. The natural pigments usually lead to dirty appearance in the fibers after processing. The purpose of bleaching is to destroy or decolorize natural pigments present in the fibers to achieve a pure white appearance before dying. In the past, the fibers were treated with chlorine and oxidizing agents in extreme conditions to achieve whitening. In recent times, hydrogen peroxide is used more commonly at industrial scale as a bleaching agent at alkaline pH and near boiling temperatures. The removal of residual hydrogen peroxide from fabrics requires a substantial amount of water, which constitutes a major problem in dyeing (Shahid *et al.,* 2016). Moreover, the radical reactions on the surface of the fabrics decrease the degree of polymerization and cause damage to fiber (Basto *et al.*, 2007; Madhu and Chakraborty, 2017). A number of alternative methods for bleaching are explored in textile industries, e.g. enzymatic bleaching with laccase/mediator systems, glucose-oxidases, peroxidases and enzymatically in situ generated peracids. However, the bio-bleaching process with laccase/mediator systems is reported to be very effective due to its specific action on coloured substances (Pereira *et al.*, 2005; Spicka and Tavcer, 2013 a,b). The use of laccases demonstrates that the enzymes decolorize or eliminate coloured flavonoids in cotton bleaching (Hadzhiyska *et al.*, 2006; Kim *et al.*, 2007; Rodriguez-Couto and Toca-Herrera, 2006) by alteration of phenolic hydroxyl groups (Pereira *et al.*, 2005; Gonçalves*et al.*, 2014).

Short duration laccase-mediated system pre-treatment prior to hydrogen peroxide bleaching enhances the whiteness of cotton fabrics along with a lower dose requirement for hydrogen peroxide at reduced temperature (Tzanov *et al.*, 2003). The combined method of laccase-hydrogen peroxide cotton bleaching with ultrasound energy also enhances bleaching efficiency in mild conditions of pH 5.0 and 60°C for 30 min and remarkably improves product quality with the desired level of whiteness. Ultrasound energy is reported to increase enzyme activity and improve the diffusion of the enzyme to the substrate surface (Abou-Okeil *et al.*, 2010; Basto *et al.*, 2007). Another enzyme, glucose oxidase (GOD), shows great promise in cotton bleaching for its specificity to produce hydrogen peroxide from glucose. This enzymatic system is quite unique in nature as it utilizes glucose in both desizing waste baths and scouring treatments, decreases water consumption and discharges less wastewater (Shahid *et al.,* 2016). Reports show that the combined one bath desizing and bleaching or bleaching using reused desized bath produces improves whiteness and mechanical properties like tensile and tear strength (Anis *et al.*, 2009; Hebeish *et al.,* 2013; Li and Hinks, 2012). GOD produces hydrogen peroxide in slightly acidic to neutral conditions at low temperatures; however, bleaching requires high temperatures of 80-90°C and alkaline pH 11.0 to produce desirable effects (Anis *et al.*, 2009; Farooq *et al.*, 2013; Ramadan, 2008). The bio-bleaching system employing arylesterases and hydrogen peroxide is also reported (Auterinen *et al.*, 2011).

If newly developed enzymatic processes could be used globally, it could save approximately 10 trillion liters of freshwater and reduce greenhouse gas emission to 30 million metric tons annually (Shahid *et al.,* 2016).

Bio-finishing

Bio-finishing/bio-polishing is the process of fiber surface modification and eliminates hair-like micro, fuzzy fibrils from the fabric surfaces or yarn by cellulases either before or after dyeing (Araujo *et al.*, 2008; Saravanan *et al.*, 2009, Choudhury, 2014). Enzyme action on fabric surface provides a softer finish and improved appearance. A ball of fuzz is called a pill and can present a serious quality problem because pills result in an unattractive knotty fabric appearance. Therefore, the main advantage of bio-polishing is the prevention of pilling. Furthermore, the removal of fuzz improves colour brightness, hand feel, water absorbance of fibers, and provides a cleaner surface structure (Ibrahim *et al.,* 2011). Traditional approaches use to remove fuzz and emit gases from combustion. Enzymatic bio-polishing is considered environment friendly approach as it replaces gas singeing and no emission occurs (Choudhury, 2014).

With bio-polishing, cellulosic fibres are enzymatically hydrolysed by the combined actions of three component enzyme systems comprising endoglucanases (EG) or endocellulases, exoglucanases or cellobiohydrolases (CBH) and cellobiases or β-glucosidases (Saravanan *et al.*, 2009). In nature, cellulolytic systems exist in differential compositions in different cellulase preparations and work in a synergistic fashion. EGs cleave bonds along the length of cellulose chains in the middle of the amorphous region, CBHs work in the crystalline ends of cellulose chains and produce primarily cellobiose. Finally, β-glucosidases break cellobiose and soluble oligosaccharides into glucose (Madhu and Chakraborty, 2017). The first reported commercially available cellulases for bio-polishing contain a combination of EGs, CBHs and cellobiases. They displayed the capacity to work on cellulosic fibers in a controlled and desired manner (Cavaco-Paulo, 1998). A number of cellulosic fiber pre-and post-treatment methods are employed to enhance the efficiency of bio-polishing, e.g. soaking in water for few hours and steaming prior to the enzymatic treatment (Pere *et al.*, 2001; Ulson de Souza *et al.*, 2013). These methods improve the hydrolytic activity of cellulases on the fibers. In particular, steaming markedly enhances EGs' activity due to the swelling of less ordered sites on fiber wall. Types of cellulases based on different types of cellulosic substrates, the optimization of process parameters and enzyme concentration are crucial to achieve effective bio-polishing. For example, the acid cellulases enriched EGs show effective bio-polishing of cellulosics (Bahtiyari and Duran, 2010; Uddin, 2010; Bai *et al.*, 2012; Saravanan *et al.*, 2013; Mojsov, 2014).

The attachment of cellulases to immobilization platforms offers the possibility manipulate the action of the enzymes and its action on fiber surface can be controlled. Various methods and immobilization matrices are used to attach cellulases to improve thermal stability and offer the potential to facilitate the reuse of the enzymes (Hirsh *et al.*, 2010, Podrepsek *et al.*, 2012; Yin *et al.*, 2013; Romo-Sanchez *et al.*, 2014). Textile-specific application includes immobilization of acidic cellulases onto specific functionalized matrices, which improves the stability at neutral pH (Dincer and Telefoncu, 2007) and the commercial cellulases immobilized onto epoxy resins show greater integrity of the enzyme than ion-exchange carrier after bio-polishing.

PERSPECTIVE ON BIG DATA IN THE TEXTILE INDUSTRY

A traditional product development process involves determining the need, development of the product and finally approaching market, with the steps usually being time consuming and isolated in nature. The marriage of electronics-textile dates back from the industrial revolution. According to Park and Jayaraman (2017) the 'integration of electronics and textiles laid the foundation for wearable sensor networks', suggesting the instrumental role of technology in textile. However, due to the current speed and nature of online business, development of data products for any industry takes place at a faster pace from various perspectives including capacity building (Shams, 2016), institutional influence (Sohag et al., 2019), adoption of IT (Trequattrini et al., 2016; Shams, 2017) and academic development (Shams and Thrassou, 2019). Hence, the reason why Dubey et al. (2016) argue that impact of Big Data on manufacturing cannot currently be overstated. In fact, data driven innovation for textile manufacturing or data products driving innovation at the textile manufacturing like other manufacturing industries are developing in a dynamic, continuous and iterative fashion with the provision of simultaneous functioning of vital processes. The flexible nature of data product development process appraises customer's feedback towards the companies, their environment and products. Previously, data product development fitted into the "lean start-up" model comprising a "minimum viable product" with the provision of intermittent refinement over time. However, to approach "time-to-market" expectations, Davenport and Kudyba (2017) *depict* the Data Driven development process as a seven-stage process; this incorporates two additional steps to the original five-stage model proposed by Meyer and Zack. This updated model adds a step at the start and involves conceptualizing the product while establishing a market feedback mechanism at the end of the process.

Step 1: Product Concept

Like other organizations, the textile manufacturing industries need to gather relevant information from the marketplace and identify how that will shape the information product. This is regarded as the introductory step as it shapes how data will be acquired. Knowledge of the information product ultimately governs which data resources could be chosen to define a probable product, the ways of collecting data and designing the sketch to develop a prototype. After considering these components efficiently, the remaining steps of DDI, for example, data acquisition, storage and retrieval, and even market feedback mechanisms could be shaped effectively. For example, Cisco India considered several factors before developing a mobile backhaul router to improve the connectivity of telecommunication network. First, it looked into key enablers for market innovation which took into account the R&D capacity, emerging market opportunity and the support of executive champions. Once the key enablers were determined, the company identified a suitable product to be developed based on market needs and an assessment of both portfolio fit and product-capability fit (Jha *et al.,* 2016).

Step 2: Data Acquisition

A comprehensive and robust conceptual model enables the precise execution of data acquisition. It is usual practice for entities to collect data which corresponds to their functional activities. As data is diversified and ubiquitous in nature, the big data platform of certain companies should appreciate all possible origins of data regardless quality (Cohen *et al.* 2009). Therefore, textile manufacturing data can be acquired from unstructured (e.g. social media responses from consumers) to fully structured sources (for instance, specific retail transactions, customer demographics, and sensor data from processes and actions) in a big data environment. For this purpose, entities can acquire or accumulate data within and outside their systems (Dwoskin, 2015).

Step 3: Refinement

Meyer and Zack (1996) identified the process of refinement as a value-adding means by either physical or logical. In addition, they envisioned refinement as the process of cleaning and standardizing data. However, to maximize the benefits of big data assets in deriving innovation, refinement should have the provision of upscaling to accommodate new data sources using advanced analytic methods (Meyer and Zack, 1996). In essence, refinement can convert an abstract data model or conceptual blueprint into implementable data structure by eliminating volatility and redundancy. Nowadays, improved application of real-time machine learning, deep learning, and algorithm processing of data elements have the ability to classify, coordinate, and epitomize customer profiles as well as search data which could augment value for customers (Kiron *et al.*, 2014).

The dynamic nature of data products for textile manufacturing facilitates, collects and processes data in such a way that actionable insights could be obtained from it. Significant data can be mined and analyzed based on engagement with stakeholder's social media posts, trends on Instagram, fashion trends and customers' buying patterns. Data can be mined with advanced models and their output is converted into an intelligible form (Hanson, 2017). Information products can also help textile manufacturing with various types of predictive algorithms that assist them in making effective business decisions. For example, fashion trends can be forecasted to inform a retailer if the latest fashion trend can help achieve a good response (Hanson, 2017). Extremely large sets of data, helps the professionals to reveal patterns, associations, and trends and thus plays a crucial role in the fashion industry. Fashion professionals can obtain refined data from big data analytics which is analyzed from structured or unstructured data, segregated into groups or categories, and then standardized to reveal the current trends and patterns in the fashion sector. Big Data could also help the textile manufacturing industry to draw new ideas, emerging patterns, shapes and styles, which may lead to sustainable manufacturing (Sharma, 2017). For example, a Spanish clothing brand Zara manufactures huge volumes of clothing for different demographics globally. It is usual that something as simple as size, body shape, colour preferences and quantity of clothing will vary greatly if the operation takes place at such a huge scale. Big data analytics is employed to gather consumer data and split it into different categories such as age, gender, price range, popular colours or other parameters. This helps companies predict the quantity and type of clothing to be sold next season. This model has saved millions of dollars by reducing the number of overproduced and redundant products.

It should be noted that just basic data analysis techniques could help an entity to make well-informed decisions. Big fashion companies like Prada, Nordstorm, United Colors of Benetton, Bulgari, Puma and Diesel extensively use analytics in their businesses according to Big data made simple. However, it is impossible for big data to redefine the fashion industry, as it requires more of art, innovation and creativity than science and numbers. Still, Big data possesses the potential for industrialists and brands to revolutionize the production process.

Data analytics could assist in effective marketing and advertising and how to optimize the supply chains in terms of decision-making. Examples include selection of products, items for stocking in inventory and simultaneously, items to be kept for made-to-order or just-in-time. Therefore, it is accepted that while intuition and innovation in design govern the fashion and textile manufacturing Big Data provides the shape and direction of production processes (Williams, 2017).

Step 4: Storage and Retrieval

Storage and retrieval are important steps in DDI for textile manufacturing, which offers the appropriate environment and infrastructure in the emerging big data ecosystem. The purpose is to adapt and combine the variety, velocity and volume of more unpolished and unpurified data and allow proper execution of advanced storage analytics tools in Big Data environment. Once the system is in place, the industry needs to realize the business value of data innovation, which is deemed crucial for determining the strategy to adopt for storage and subsequent planning. This is inclusive of the requirements for compliance, data retention policy, use of technologies for the reduction of duplications, easy access of data, and recovery plan for disaster. In succession, **r**etrieval offers the opportunity to integrate cutting-edge query and search processing capabilities compatible with products and storage platforms (Davenport and Kudyba, 2017).

Cloud technology is recognized as a powerful architecture to integrate frameworks for parallel data processing and assist users in accessing cloud resources and deploying programs (Warneke *et al.,* 2009). It can integrate the computing utility model with rich computations, infrastructures and storage so that cloud services could offer an effective innovation environment (Gunarathne *et al.,* 2013). For example, Map reduction, an innovative scientific computation model (Zhifeng and Yang, 2013), could perform accelerated processing of large volumes of data in cloud environment with the scope for parallel operation carried out by a cluster of servers (O'Leary, 2013). Big Data could transform into unified open-source environment with the advancement and incorporation of analytics (i.e., HDFS, Hadoop Distributed File System). This, according to Dudley et al. (2016), has simplified the loading, extraction, transformation and processing of large and diverse data sets.

Another interesting example includes, Fashion Cloud, a German start-up to provide a platform for digital cooperation between fashion brands and retailers. The platform ecosystem also includes some enterprise resource planning (ERP) providers (integrations). For brand companies, Fashion Cloud manages all brands together on the same platform. This has enabled the distribution of content information (product information, stock levels) a much simpler process, as well as facilitated the availability of content for the retail partners at the same time. For retailers, Fashion Cloud allows access to marketing and product images from more than 250 brands in a repository which is constantly evolving. Brands are allowed to upload marketing material, product data and logos to the platform and set characteristics or features for a given product, e.g. season and expiration date. Fashion Cloud allows direct application programming interface (API) access to an image database enabling fully automatic product data flow into a retailers ERP system based on subscription.

Step 5: Distribution

Success and innovation of data product is influenced by maintenance of structure and life-cycle of data products in an industry due to their ubiquitous nature. For example, in case of data-driven innovations with shorter lifespan, data are removed from archives immediately after the value of data becomes meaningless and becomes depleted. After careful observation and exploration of benefits and challenges of global business expansion, many entities have reshaped their data infrastructure into a geo-distributed data platform with real-time sharing and updating of data. It has ultimately enabled fine-tuned control of data access and availability.

However, with the evolution of the app-economy, the use of apps on mobile devices has increased significantly, thus necessitating the modification of content configuration and design (Davenport and Kudyba, 2017) to accommodate the requirement and specification. At the same time, the distribution of data products through clouds has enabled the entities to benefit from flexibility and simplicity, which in turn increased time to value.

Step 6: Presentation

Presentation is a decisive step for a data product to be aligned with distinctive markets. According to Meyer and Zack (1996), any industry should combine a unique business and operational model with certain set of analytic capabilities so that presentation and addition of value to data could support its stakeholders. This leads to an effective evaluation of the product (Meyer and Zack, 1996). Although knowledge-based view (Nickerson and Zenger, 2004) and exponential digitization have influenced the level of adoption for analytics, the user-interface needs consideration for the diffusion of product innovation. However, simple data products are appropriate for most of the consumers, more advanced analytics based data products (real-time calculations generated through machine learning) provides entities with competitive edge (Davenport and Kudyba, 2017).

Step 7: Market Feedback

A well-structured customer feedback mechanism is essential to obtain customer insights and determine the competitive trends in the data driven industry. This helps to achieve competitive advantage in the industry by analysing whether a data product needs to be innovated or modification of an existing innovation would suffice the purpose. This step is in agreement with analytics-based data-driven innovation in a "lean start-up" context that focuses periodic refinement over time to allow continuous innovation. For collection of clear feedback from customers, social media response is proved to be worthwhile by many firms. In addition to direct comments on social networks, online polls on a particular web page (*i.e*. on Facebook) could judge user satisfaction. Sometimes online flash surveys, interactive blogs could be employed to appraise customer impressions regarding existing data products (Rajpathak and Narsingpurka, 2013). In addition, Bootstrapping Usability Test can be used as an effective way to obtain unbiased feedback through simulating a real usage of a data product.

THEN WHAT IS HINDERING DECISION-MAKING VIS-À-VIS BIG DATA APPLICATION IN TEXTILE?

Traditional and cultural aspects of decision-making in developing countries

In an Asian context (a vertical-collectivistic context, according to Rockstuhl et al., 2012), the LMX is not singular, meaning that it does not extend only to workplace relationships. But the LMX in vertical-collectivistic spheres is multi-dimensional, which signifies that relationships between leader and followers stretch beyond organizational boundaries. These then enter the arena of social exchange and involve subjective and emotive domains such as affect, contribution and allegiance or loyalty (Javed, Khan and Quratulain (2018; Dienesch and Liden, 1986). In this perspective, in the highly vertical-collectivistic societies of southeast Asia, decision-making with regards to strategy, particularly with regards to investment in new technologies such as biotechnologies, rest largely with the elders (who also owns the capital and means of production). The cultural issue is intertwined with other critical issues, that of generations and education.

Generation conflict and education

Most of the textile plant owners in Southeast Asia are among the Baby Boomer generations (1946-1964). They felt the hardship in the aftermath of the War and developed economic ethos which centre on perspective of economic rationality. The economic and political choices made by Baby Boomers have been fiercely criticised by Millenials (the next generation). The main charge is that Baby Boomers wretched the economy and made political decisions that disadvantaged Millenials who inherited dysfunctional economics systems and international relations (Sternberg, 2019; Brill, 2018; Gibney, 2017). However, these views are challenged by others (Illing, 2019; Pruchno, 2012). Regardless of the 'blame game', the reality of the generation conflict is tangible and ongoing. The potency of this conflict is exacerbated in the vertical-collectivistic context of Asian culture, because it a cultural vice to challenge the elders (Vauclair et al., 2017). The second issue of contention is education. By education, we do not imply only schooling and training; but our perspective on education encapsulates formal learning as well as informal learning through exposure to globalization (Berkup, 2014). Current managers and technicians in the textile industry are from Generation Y (Millennials) and Generation Z (or i-generation also known as Generation Net). The latter two generations have been educated in technological environment, with exposure to the internet and advanced processing technologies and information technologies (Park and Jayaraman, 2017; Turner, 2015; Shatto and Erwin, 2016; Berkup, 2014), including Big Data in the 21st Century. They also have exposure to the many impact of globalization via social media, ease of travel and greater language abilities, etc. The latter generations also are increasingly conscious of environmental issues (Dolot, 2018; Patel, 2017) and therefore more willing to invest in more environmentally friendly biotechnologies. However, the weight of culture, the lack of control over capitals and means of productions as well as economic rationality of the textile plant owners impede decisions to implement new biotechnologies. Our perspective does not seek to blame owners but one that emphasizes education and awareness raising among Baby Boomer owners who could be gradually introduced to the benefits of new technologies and Big Data in terms. Such benefits include cost-effectiveness, image-enhancement and environment-friendliness, etc. (Rehman et al., 2016).

CONCLUSION

Biotechnological progress has opened many windows for sustainable development (Petruzzelli *et al.*, 2015; Coccia, 2017). As Chen et al. (2016) contend, biotechnology holds strong relationship with sustainability in textile manufacturing with the incorporation of industrial scale enzymes and their related processes. We can view sustainable textile development as processes where the needs of present manufacturing are fulfilled without reducing the opportunity for future incorporation of greener production systems aligning with increased production demand. In this regard, sustainable development encompasses both harmony and synergy in the utilization of resources, process of investment and technological development. The ultimate objective is to increase the opportunity to fulfill both current and future needs in efficient and responsible manner (Broman and Robèrt, 2017). In addition, industrial sustainability takes into account the sustainable manufacturing and processing with the objective of ensuring environmental and social sustainability (Turker and Altuntas, 2014), which is a promise that textile biotechnology could offer. However, an industry is deemed sustainable when it can assure that present demands are met without harming the potential for meeting future generation's needs.

Environmental and market implications

Biotechnology can ensure greener processes in textile industry because biotechnology-powered manufacturing and processing systems, essentially enzymatic textile processing, use less materials and energy. It guarantees reduced greenhouse gas emission, less dependence on non-renewable resources and more usage of renewable resources (Gavrilescu, 2010). Biotechnology-fueled sustainable products, such as textile enzymes, are better performing, more profitable, durable, less toxic, easily recyclable, and biodegradable in the environment (Bolis *et al.*, 2017). In the current competitive and challenging business environment, enzymatic biotechnology is promising in regard to enhancing sustainability concepts in the textile manufacturing supply chain. Decisions to use Big Data can enable organizations to achieve "competitive position" in the world market by replacing chemical-based processing (Ansari and Kant, 2017). By focusing on biotechnology, organizations have adopted sustainable supply chain management (SSCM). Sustainable supply chain management is an integration of three facets of sustainable development: economic contribution, social performance and environmental performance (Khodakarami *et al.*, 2015). The scopes of biotechnology to textile industrial processes result in potential as well as opportunities for assessing the frameworks of current and anticipated economic, societal and environmental challenges including sustainable development, cost minimization and business competitiveness (Ribeiro and Shapira, 2018; Chen et al., 2016; Rehman et al., 2016).

Big Data can be a significant aspect to bring to light where biotechnology has used enzymes as an alternative to the harmful chemicals in the textile industry and gained customer approval. The use of enzyme has created scope for biotechnology to reduce costs in manufacturing process, less consumption of water, electricity and fuels and improvement in the final product. This contributes to business competitiveness. Apart from the cleaning process, textile enzyme is being used in the treatment of cotton fibers. Enzymes enable a faster and softer treatment process which results in less chemical and energy consumption (OECD, 2011). However, there is critical work needed in order to mend the generational gap between owner-decision makers and their followers on whom the future of the textile industry and environmental sustainability rests. The practical contribution of this paper goes beyond economic rationality for the companies using biotechnology in textile manufacturing. At the time when scientists warn of climate emergency (Ripple, 2019), this paper contributes to promoting means by which emissions could be reduced globally. Ultimately, increasing the use of Big Data to inform the use of biotechnologies in the textile industry will be largely played on educating owners about the benefits that may not necessarily entrench on economic rationality.

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