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Sustainable Packaging Practices Across Various Sectors: Some Innovative Initiatives Under the Spotlight

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ABSTRACT

Sustainable operations and supply chains are the desperate needs of the global business environment. Governments worldwide are enacting laws to reduce plastic products and encourage biodegradable packaging. A range of global practices is visible in various business operations, including designing, manufacturing, storage, and distribution. This paper has focused on some of the innovative and sustainable packaging practices adopted by companies in New Zealand and other parts of the world to improve operational efficiency and environmental sustainability towards better profits and corporate social responsibility. The paper is based on various articles from trade and academic journals highlighting the importance of sustainability in the packaging, operations, and supply chain domain. The literature review indicates that while there is an appetite for changes in the packaging materials toward sustainability, users or shoppers are still not fully prepared to pay for such changes. There are many examples of sustainable packaging practices undertaken by companies, researchers, and innovators worldwide. However, it may not be pragmatic to do away with all the plastic packaging from every product because consumers still want to enjoy the packaging's convenience. So, while people might be shocked to see the frequent imagery of wildlife crippled or killed by discarded packaging not every consumer is putting the planet's health ahead of their fresh choice of produce. The challenge ultimately lies with the food and other industries to innovate their packaging to ensure they are biodegradable, recyclable, sustainable, and affordable. Fortunately, the changing consumers' awareness of sustainable packaging and perceived readiness to accept some of the costs provides significant optimism.

Keywords: *sustainability, packaging, plastics, operations, supply chain, innovation, practices*

1. INTRODUCTION

Food safety and environmental sustainability are important issues in today's highly connected global businesses. Consumers are becoming more concerned about the quality, safety, and price of the foodstuff they buy and consume. Carol Ward (Zespri CIO) says that consumers care about what their food is wrapped in, where it comes from, and whether it has been grown in an environment-friendly manner (Trower, 2020). As a result, they are becoming more and more sensitive to sustainable operations and supply chain issues, including carbon footprints, food miles, industrial emissions and wastes, and food packaging. New Zealand is prominent for its clean-green image and orientation towards protecting the environment, and its care for natural resources. The Hawke's Bay region of NZ grows various types of fruits, including pip fruit, stone fruit, apples, and grapes, and the region also enjoys adequate sunshine and rainfall (Hastings, n. d.). As NZ apples and other fruits enjoy a high-quality reputation worldwide, their supply through sustainable packaging has become even more critical for companies to maintain their brand image. This paper has highlighted many promising sustainable packaging practices (**Figure 1**) by different organizations across the world.

Why is this paper important? Well, let us justify this with an example. XYZ Ltd. is a medium-sized business in the Hawke's Bay region of New Zealand that started as a grower and packer of conventional fruits for the domestic and international markets. It began with just 8 acres of land but now grows, packs, and exports fruits to global markets and manages over 100 hectares of land, 95% of which is used to grow apples and the remainder used for peaches and pears. Over 98% of XYZ's apples are exported to the international markets, and less than 2% are sold domestically. XYZ follows a range of sustainable packaging and supply chain approaches in its operations. Due to the increasing export footprint of XYZ, it is vital to focus on its sustainable packaging and learn from the global packaging practices on how to make its sustainability efforts even better and more effective.

There are lots of sustainable practices occurring in many businesses, but they are mostly scattered and might go unnoticed by researchers and practitioners of sustainable packaging. Similar to XYZ, there might be many other companies across the world that could learn from each other's sustainable practices, but that would not be possible unless those practices are documented, collated, and made visible through a review process. Many journal articles have focused on research-related articles on sustainable packaging materials but very little has been reported on the commercial packaging practices occurring in different parts of the world in various sectors. This paper has tried to fill this gap by reviewing several articles from trade magazines, and academic journals on sustainable business practices, research, and developments. On one hand, the paper aims to encourage the current practitioners to continue doing their good works, while on the other, motivating potential practitioners toward sustainable packaging in their businesses.

The objectives of this paper are to (a) review the current sustainable packaging practices in New Zealand and

across the world, (b) investigate the factors affecting sustainable behaviours from users, reveal the research gaps and opportunities, and (c) suggest strategies to communicate packaging sustainability to consumers.

The paper is based on various articles in trade magazines, newspapers, and academic journals highlighting the importance of sustainability in the packaging, distribution, retail, operations, and supply chain domain. The layout of the paper is depicted in **Figure 1** with various issues, research efforts and practices toward sustainable packaging. The block diagram (**Figure 1**) is a snapshot of the topics and subtopics that have been covered in the paper, and this is expected to facilitate the ease of reading and understanding of how various issues and subtopics relate to the general theme of the paper.

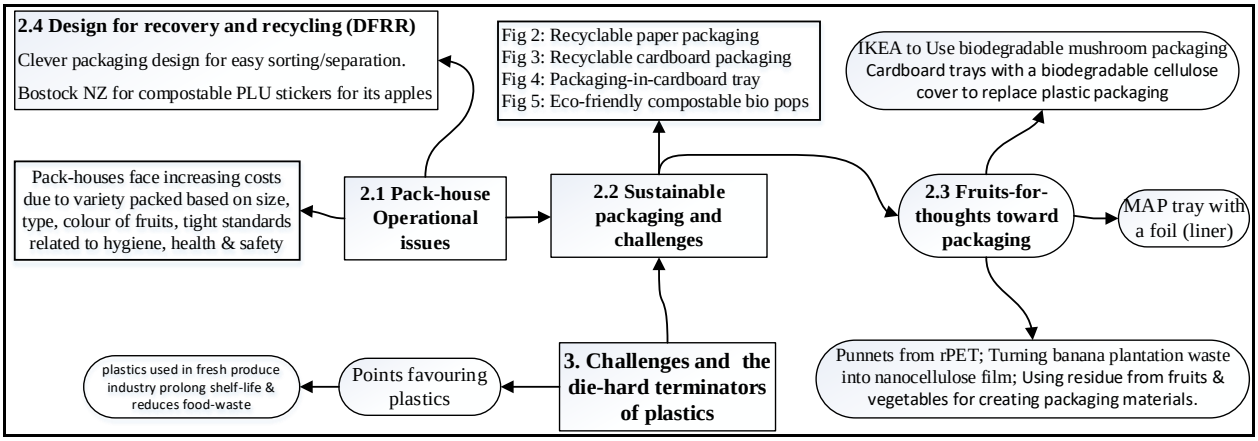

Figure 1 Various Issues and Practices Toward Sustainable Packaging

2. LITERATURE REVIEW

There are many articles reported in trade and academic journals which deal with different issues and various types of sustainable practices across many countries. They also deal with a range of operational issues and challenges, including the use of modern technology, precision farming, sustainable packaging, and biodegradable materials in the retail and horticulture industries. Boldizsár *et al*. (2022), for example, feel that the primary task of packaging is to preserve the quantity and quality of goods in the entire distribution chain. Packaging also plays a vital role in marketing, purchasing, and connecting products with customers. However, packaging must also protect the environment from the harmful effects of dangerous goods. There are articles highlighting the advantages and disadvantages of synthetic (plastic) packaging. According to Sayadi *et al*. (2022), synthetic packaging materials are used in different industries due to their properties including low cost, excellent mechanical behaviour, and good barrier against moisture loss. But the non-degradability of plastic materials has created many environmental problems.

There has also been growing awareness in the areas of food safety (Russell, 2020) and packaging materials (Reichert *et al*. 2020), and packaging technology (Boldizsár *et al*. 2022). Reichert *et al*. (2020) extensively reviewed synthetic and non-synthetic materials for packaging and textile applications and provided a holistic view of bio-based packaging options, their processing, and their recycling. They concluded that the bio-based polymers belonging to the polyesters group are generally slow to biodegrade, and thus their structure needs to be modified through copolymerization to accelerate their biodegradation. Similarly, Erika *et al*. (2020) evaluated the perception of intelligent packaging in Slovakia as ecological innovation through the Kano model. Their analysis indicates that customer awareness of innovative packaging in the context of the bioeconomy is still low. However, from the perspective of intelligent packaging, Slovak customers can play a key role in the management of innovation processes for the bioeconomy. Their study (Erika *et al*. 2020) suggests that age is also a limiting factor in the implementation of intelligent packaging. For example, elderly consumers have a lower innovation but the highest need for packaging innovation. Moreover, they are also not interested in all packaging functions. However, consumers of all ages require ecological innovation in the packaging but with different intensities of influence. Palsson and Sandberg (2020) consider packaging as a complex matter due to increased legislation and consumer awareness of the environmental performance of packaging, globalisation, and the need for short lead times. The trade-offs in the packaging systems have been analysed through different models including packaging scorecards, and life-cycle assessment (LCA).

In the wake of the Covid-19 pandemic, researchers are also focusing on biomedical waste (BMW) management and the well-being of people. In this context, Pandey *et al*. (2020) explored the BMW process, practices and disposal adopted by some hospitals in Pune (India). Their study showed that government hospitals and their healthcare staff were casual in their approach to the BMW management process as compared to private sector hospitals. According to their cited reports, the developed nations produce about 1-5 kg of waste per bed, while developing countries generate 1-2 kg of waste per bed (Saini *et al*. 2005; Qureshi *et al*. 2007 cited in Pandey *et al*. 2020). The improperly managed biomedical waste in health care could create grave consequences for people and communities. Many incidents have been reported in the newspaper about small clinics throwing biomedical waste at general waste disposal facilities creating a source of spreading infection and

diseases through rag pickers and stray animals. The situation in government hospitals is the same as in small clinics where bio-medical waste often is mixed with domestic waste. However, a few private hospitals have proper mechanisms for the disposal of waste because they care for the environment, their patients, and their brand reputation.

Researchers are trying for either a partial or total replacement of synthetic polymers with edible or biodegradable materials. In this context, Sayadi *et al.* (2022) report that natural biodegradable polymers including protein and polysaccharide-based films might be well-suited for packaging due to their environmental compatibility. The use of biopolymers (e.g. alginate, gelatin, pectin, etc.) in the forms of coatings and films can restrict oxygen availability and prevent moisture loss, and can increase the shelf life of food products. In the efforts toward the reduction of plastic packaging, business practitioners in different parts of the world are also in sync with the researchers. For example, moving toward plastic-free packaging, Zespri has committed to making all packaging 100% reusable, recyclable or compostable by 2025. It has shared its commitments with growers, consumers, and suppliers at the NZ kiwifruit conference (Momentum 2020: Standing Up & Standing Out). Zespri also committed that its plastic packaging will be made from at least 30% recycled plastic, and by 2030, it will reduce its packaging footprint by 25% per kg of fruit produced. We already have 95% of our packaging used to transport kiwifruit to market as cardboard, but there's more to do. Some of the other actions by Zespri include reducing the weight of liners in cardboard transport packs, trialling fibre-based solutions for pocket packs, implementing improved recycling options, and eliminating all unnecessary packaging (Trower, 2020). Yet, another related topic on the talk menu is the plastic stickers on the fruits. In this context, Skerrett (2019) reports that the price-look-up (PLU) stickers are necessary for the checkout staff to identify the fruit quickly. However, they contribute to plastic waste with about 1 billion PLU stickers each year on NZ apples. New Zealand's largest organic apple grower, Bostock NZ, conducted a trial of compostable PLU stickers for its apples to mitigate this problem. The trial was successful and would roll out more compostable stickers for European customers and the Braeburn apples for the US and NZ markets. The company would prefer not to use stickers; however, many customers and retailers require them because they would not quickly identify organic apples from conventional ones without stickers.

2.1 Pack-house Operational Issues

There is also a range of operational issues and challenges related to packaging and packhouses in the horticulture sector. According to Fitzgerald (2003), several smaller pack-houses in Nelson have ceased their operations due to the increasing costs in packaging, and increased variety of lines packed (based on size, type, and colour of fruits). Moreover, the tight standards and regulations related to hygiene, health and safety have also resulted in increased operational costs. To meet the growing trend of customization and quality fruits, many pack-houses had to invest in colour-graders and labelling machines to label each apple for export with an ENZA sticker. There was also an increased amount of paperwork involved in fruit-packing to facilitate its traceability which leaves behind a trail of documents to enable the supermarkets to receive a carton of fruit with details about their origin. Traceability is very reassuring for supermarkets and customers, but, for those in the industry, the harvest season is a stressful time with an increased workload in packing. Although some growers commented that they would be financially better off packing their fruits, however, it was not worth the time and stress.

2.2 Sustainable Packaging and Challenges

According to National Geographic (Stauffer, 2019), if a retailer shrink-wraps a cucumber in polyethene, its shelf-life improves from 3 days to 14. However, the same plastic will last more than a century and will probably make it to the oceans and contaminate water and aquatic life. Of the 78m tons (MT) of plastic packaging produced each year globally, only 14% (10.92 MT) gets recycled, while 9 MT of plastic escapes the collection annually. The sustainability and packaging industries are inextricably connected. The Dutch company, Argos Packaging, has launched sustainable cardboard packaging made from locally grown elephant grass with no pesticides, irrigation, or fertilizer. A plot of elephant grass absorbs four times more CO2 than the same size plot of planted trees. Argos is also working innovatively for the snack cups, made with 80% cardboard and a more sustainable substitute for the regular PET versions (Cardboard fruit & vegetable packaging, 2020).

Figure 2 Recyclable Paper Packaging
(*Source:* Delphine, 2020)

Figure 3 Recyclable Cardboard Packaging
(*Source:* Fernández, 2019)

Delphine (2020) argues that the plastic era is over, and it is logical to have 100% recyclable cardboard packaging with two advantages: (i) the openings in the cardboard (**Figure 2**) make apples visible to customers, and (ii) they are difficult to be removed by anyone if the packaging remains intact. Similarly, McGregor (2019) reports that the battle against plastic in the fresh produce industry has intensified, and many companies are looking at reducing plastic use in packaging. Most supermarkets are already charging for plastic bags and are under pressure to remove plastic from fresh produce. It is also observed that New Zealand shoppers have gradually started feeling proud of using their jute or fabric bags while shopping in supermarkets.

Companies are focusing on replacing plastic with paper or cardboard, which seems popular with consumers. For example, Fernández (2019) reports that cardboard is the highest-rated packaging material by Spanish consumers, with the most used being cardboard, plastic, and wood. The study shows that 75.2% of consumers prefer to purchase products in cardboard packaging, compared to only 11% in plastic. Of the total cardboard production in Spain, 15% gets used for fresh fruits and vegetables (see **Figure 3**). Voorde (n. d.) adds that plastic is gradually disappearing from the fruit and vegetable shelves at Delhaize, which is trying to move to plastic-free shelves, but that is not feasible for certain products, including sliced vegetables.

Another company, Top-Seal Packaging, offers the same quality and freshness of produce but reduces plastic use by about 25% from the typical clam-shell lid. In addition, it promotes a longer shelf-life with perforated film, and its peelable format allows for re-sealing of the packaging depending on the need. The Top-Seal also provided suppliers with an opportunity to stack more products atop one another to transport more and reduce transportation costs and environmental impact (Stauffer, 2019). Similarly, Zwager Techniek (2020) provides a packaging-in-cardboard tray (**Figure 4**) that can lead to 80% plastic reduction and more sustainable packaging with a paper seal tray with a foil (liner).

Figure 4 Packaging in Cardboard Tray
(*Source:* Zwager Techniek, 2020)

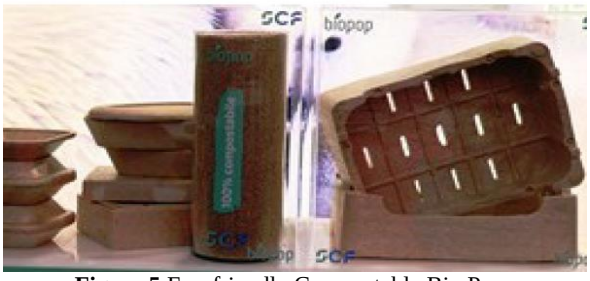

Figure 5 Eco-friendly Compostable Bio Pops

According to McGregor (2020, Jan), the packaging industry needs to evolve and adapt as consumers and retailers want more sustainable packaging for fruits and vegetables without compromising shelf-life. In this context, AVI Global Plast (India) offers a range of sustainable products, including punnets with recycled content without compromising their physical properties. These punnets are made from rPET films containing 90% recycled content. In 2019, AVI helped recycle 111m bottles to produce punnets in compostable materials providing equal strength and performance, and it has developed various types of punnets, including open-top, heat-sealed, and flow wraps. Similarly, Tim Newton (Tech Director BerryWorld) claims that their punnets are 100% recyclable and contain 50-80% rPET (recycled plastic). They continuously test and review many packaging formats to supply the UK market with a more sustainable yet commercially viable option without compromising food quality or shelf life. Their goal is to ensure 100% recyclable packaging by 2021, with at least 80% rPET content by 2025. BerryWorld's packaging has reduced the use of plastic sporks from 57 tons to 7.2 tons annually. In addition, reducing the thickness of some punnet formats has further reduced plastic usage by 71 tons. However, there is no one-size-fits-all solution. So, they align with consumer attitudes and retailers' demands to supply tailor-made sustainable packaging options in Europe and beyond (Berry World, 2020).

2.3 Fruits-for-thoughts Toward Waste Minimisation and Packaging

In recent years, the interest in reusing waste materials (viz. peels, husks, pomace, seeds, etc.) of agro-industrial processes increased significantly due to the enormous amount of these food residues, the problems of their disposal and the recognized value of by-products as a source of bioactive compounds (polysaccharides, fibres, phenolic compounds, vitamins, minerals, etc.). Dilucia *et al*. (2020) considers fruit and vegetable by-products as the most abundant food waste from edible oil, juice, wine, or sugar production processes. The residues from these processes are generally discarded or used as animal feed or composted, but they are a great source of bioactive compounds, including polyphenols, vitamins, and minerals. The amount of residue with their potential application in packaging has been estimated at millions of tons per year. For this reason, many researchers are making great efforts to reuse these valuable resources. Some of the most recent research deal with fruit and vegetable by-products used to improve packaging systems' physical, mechanical, antioxidant, and antimicrobial properties. Nora *et al*. (2017) reported that about 1.3 billion tons per year of food gets wasted from the production stage to consumption. They identified the potential utilization of an abundance of seasonal crops, crop remains, and the by-products of fruit and vegetable using appropriate technologies to convert food waste into value-added products. According to Doyle (2019), some researchers (Arcot & Stenzel, University of

NSW, Australia) have developed a process to turn banana plantation waste into a nanocellulose (NC) film used in food packaging. Unfortunately, the banana fruit only comprises 12% of the plant, and the rest gets discarded after harvesting the fruit. The banana-growing business is particularly wasteful compared to other fruit crops because the plant dies after each harvest. Researchers were mainly interested in the pseudostem (the layered-fleshy trunk of the plant). Some of it is used for textiles and compost, but the rest is a colossal waste. Stenzel adds that it is possible to get NC from every plant. However, some plants are better than others in terms of cellulose content. NC is a high-value material with various applications, particularly single-use food packaging ending in landfills. This new material is recyclable, biodegradable, and non-toxic, but there are some challenges in the way of nanocellulose. For example, Ghislain *et al.* (2020) reported that plant-based NC is a biodegradable and non-toxic material with mechanical, rheological, and gas barrier properties better than oil-based plastics. However, the sensitivity of NC in humid settings and lack of thermo-seal ability have proven to be significant obstacles to its breakthrough in various sectors, including food packaging. On the positive side, attempts have been made to provide a hydrophobic character to NC through chemical modifications in recent years. Other extensive works reported on NC applications in food packaging include coating, layer-by-layer, casting, and electrospinning. However, packaging manufacturers have not shown much interest in the applicability and processability of NC due to the lack of guidelines in implementation.

Taking the sustainable journey even further is an innovation company called 'Apeel Sciences' which is focused on reducing food and plastic waste. Stauffer (2019) reports that 'Apeel Sciences' uses plant-derived materials in natural peels of fruit and vegetables, seeds, and pulp, to create packaging solutions that are both edible and protective enough to replace the need for plastic. They aim to double or triple the shelf life of many products, promoting sustainable growing practices, better food quality, and less waste! It has begun partnerships to distribute Apeel avocados, asparagus, and limes to the European market. Another alternative the industry is exploring includes corrugated packaging boxes made from recycled material which can be recycled again after use. Similarly, Mestre (2020) adds that with the increasing demand from consumers for packaging with a minimal environmental impact, Gruppo-Fabbri has developed Nature-Fresh - a home-compostable stretch film that combines biodegradability with elasticity transparency, breathability, and mechanical resistance of plastic.

There are also some other aspects of plastic packaging that do not cut ice with many consumers. For example, plastic is sourced from petroleum, consumes much energy in manufacturing, and creates enormous pollution, damaging waterways, and harming animals and natural resources. In contrast to this, mushrooms and other plant-based packaging use a fraction of the energy required to make plastic, produces minimal carbon emissions, and naturally break down into the Earth with no pollution. As a result, the home décor giant IKEA extends its commitment to sustainable packaging using mushroom-based packaging that eliminates the need for other wasteful materials. The mycelium-based material (called Mushroom-Packaging or MycoComposite) is grown in a controlled environment in less than a week, providing a sustainable option for packaging requirements. Mycelium also works with other plant-based materials, including hemp, husk, oat hulls, and cotton burrs (IKEA commits to biodegradable mushroom packaging, 2020). Similarly, a London-based expo showcased futuristic eco-fabrics that use plants and natural waste instead of artificial fibres. Some interesting ones on display included cactus leather, wool from pineapple leaves (sourced from the leftovers at juice bars), and innovative sportswear embedded with live bacteria to neutralize the body's odour. Millions of good bacteria encased in panels in the key areas, such as armpits, are activated when the wearer sweats (Cactus leather & pineapple-leaf wool, 2020).

Dilucia *et al.* (2020) feel that the environmental impact of petroleum-derived polymers paves the way for developing greener alternatives by replacing conventional plastics with renewable and biodegradable materials. In this context, ideal candidates for green polymers should be edible systems (i.e., materials with only food-grade components in their composition). Fruit and vegetable by-products could gain great interest from the perspective of more sustainable packaging. The need for edible ingredients is limited to the film-forming matrix and plasticizers, and any other additive should be of natural origin. Many fruit and vegetable by-products have been proposed to improve the properties of synthetic or bio-based plastic materials, which in many cases were applied with success to actual perishable products. The authors reflect that despite the many advantages, very few residues from the processing of fruit and vegetables have been used appropriately. Therefore, more conscious efforts need to be made by sustainable food processing technology to use their potential effectively. According to Philipp Breitenberger (Sapori di Marca), the organic sector strives for sustainable packaging solutions because its buyers from Europe and Asia require plastic-free packaging. Sapori developed packaging from recyclable paper and cellulose hydrate to meet customers' expectations and their organic kiwifruit Kiwiny. They used policart paper pack which is biodegradable in a marine environment and replaces plastic flow packs. The cardboard trays with a biodegradable cellulose cover replace the plastic packaging material for 500gms (New recyclable packaging solution., 2019). Directing similar efforts toward sustainability, Team-Pack GmbH (2019) developed a biodegradable 26cm-wide-bag of parchment paper so that the asparagus could be placed crosswise. The company also presented a 2kg capacity crate from 100% cardboard with or without a handle. Team-Pack is also open to other sustainable alternatives including jute bags - coated with PE on the inside.

One of the critical considerations in packaging operations is to pick the appropriate packaging option based on product, weight, humidity, temperature, and the distance to which it will be shipped. In this regard, the point that favours cardboard containers is that they can be recycled at the destination after travelling long distances, while reusable plastic containers must be returned, involving extra shipping and sanitation costs. Other advantages of

cardboard packaging include (a) its safety and hygiene as each fresh product is placed in a new cardboard box to avoid contamination from the previous usage, especially in the situation like the Covid-19 pandemic, and (b) the potential for customised presentation through printing that may improve corporate brands, convey information, enable better consumer shopping experience, and improve sales. Boxes from corrugated cardboard with common-footprint-quality (CFQ) standards are perfect for distributing and transporting fruits and vegetables. Ostaijen (from Corrugated Board Association) states that increasing sustainability was paramount in developing their CFQ boxes by using the minimum amount of cardboard but ensuring sturdiness and efficient loading grade. Other considerations included stack ability and specific fruit and vegetable sustainability. Similarly, Scurria (SCF Packaging, 2020) claims that they are the first company to produce low-thickness packaging called Biopop (**Figure 5**) that is shock-absorbent and 100 % compostable in 4 weeks. Scurria adds that the Bio pop is an innovative eco-friendly alternative to storing fresh products and could be the future of disposable options as punnets, trays, and containers of all kinds and can be disposed of with organic wastes.

Siahaan and Purwanto (2022) studied the effects of plastic crate and cardboard box packaging on the physical quality of fresh chilli by measuring the weight loss, colour change, hardness, and water content changes after storage over a present time. They found the cardboard packaging better than plastic crates in terms of weight loss. The weight loss for plastic crate packaging was 27.5% while it was 24.8% for cardboard packaging after storage.

Shershneva (2022) reported the fourth generation (4G) of biodegradable food packaging materials which have acceptable organoleptic, mechanical, and chemical properties and can be an alternative to synthetic polymers. These bioplastics with antibacterial properties can extend the shelf life of products and can be smart packaging to retain the freshness of the products. However, the barriers to the mass production of biodegradable materials are their high production cost and high demand for biomass. The process of obtaining biomass could result in soil depletion, the release of carbon dioxide and methane, and the leakage of harmful chemicals into groundwater.

Some of the innovative materials suggested by Shershneva (2022) for use include (a) biodegradable packaging with silver to retain the food quality, freshness and texture longer, however, the metal content increases the cost of packaging and its recycling; (b) biodegradable film with antibacterial agents for packaging fruits and vegetables and increasing their shelf life; (c) packaging with the addition of cheese whey which acts as an antimicrobial agent in packaging material to extend the shelf life of food products; (d) biodegradable film based on bacterial exopolysaccharide (xanthan) for meat and fish packaging with a positive effect on sensory, physical, chemical and microbiological indicators; and (e) biodegradable container from gelatine and natural polysaccharides for dairy products. Sayadi *et al*. (2022) reported metal and metal oxide nanoparticles including copper, titanium, silver, zinc, ZnO, MgO, and TiO2 (titanium dioxide) for antimicrobial packaging applications. TiO2 is used as a pigment in food packaging and food products.

2.4 Design for Recovery and Recycling (DFRR)

Recycling packaging materials after their usage is critical to sustainable packaging, however, sorting, separation, and disposal of packaging materials do have some challenges in practice. In this context, some researchers have focused on appropriate packaging design (Nemat *et al*. 2020; Boldizsár *et al*. 2022), and the factors or elements (Konstantoglou *et al*. 2020) that affect the design. Nemat *et al.* (2020) argued that clever packaging design could allow easy and proper sorting or separation. They studied six types of yoghurt and cream packaging across 15 households in a Swedish city and revealed that some of the selected packaging waste is not adequately separated and sorted. They concluded that food packaging design based on user-centred needs could affect consumer decisions on properly sorting packaging waste, enabling improved material recovery. They added that design should focus on the package's visual attributes, material selection, and waste sorting-related functions. Highlighting the importance of packaging design, Konstantoglou *et al*. (2020) identified and evaluated packaging elements in the food industry to examine their relationship with consumer behaviour in buying food products. They conducted exploratory-factor analysis (EFA) on a sample of data to explore the factor structure of these elements in the general population. The EFA of the packaging items resulted in seven factors, including informational content, content protection and recognition, competent functioning, geometry, environmental friendliness, endurance, and colouration. The findings were informed by the consumer attitudes and predispositions towards packaging, thus having practical managerial applications. Researchers suggest that by identifying the importance of crucial packaging elements, the manufacturers in the food industry should adopt a concurrent approach to include marketers, logistics experts, food scientists, and environmental managers in the design and development of packaging in the food supply chain. According to Merabtene *et al*. (2022), food packaging provides food safety, enables marketing, and facilitates ease of transportation. Packaging protects the content from crushing or environmental impacts. However, one of the other goals is to reduce the overall volume of packaging waste by using strong, thinner, lightweight, and recyclable packaging materials (e.g., paperboard, flexible paper, bio-monomer, and biodegradable alternative).

Boldizsár *et al*. (2022) reflect that the design of appropriate packaging during production is critical in achieving efficiency and sustainability. Therefore, large companies are focused on the efficient and sustainable integration of packaging, product, and supply chain systems. Nemat *et al.* (2020) added another dimension by saying that proper food packaging design could enhance consumer decisions in sorting packaging waste. Current food packaging seems to be designed as containers before and during the consumption of contents and not for sorting the packaging after the contents are consumed. This could be done by paying attention to its functions, form, texture,

colour, and recyclable materials that could be separated easily from each other. However, this study reveals that only choosing recyclable materials does not guarantee the proper separation and sorting of the packaging. Waste separation and sorting is a process that must be easy and convenient for consumers. Hence, packaging functions, including the ease of emptying, cleaning, separating, and folding, are the most likely features that could be used to enhance proper sorting. García-Arca *et al*. (2020) proposed a systematic and dynamic method to connect decisions about box dimensions with the measurement of overall efficiency and sustainability of supply chains. This method was applied successfully in three firms with different logistics systems (pallet, container, and parcel). This novel approach is considered particularly useful in the research domain to open new lines of study and in the professional domain to improve competitiveness and sustainability.

Boldizsár *et al*. (2022) emphasise that the creation of green logistics and supply chains needs the joint efforts of governments, logistics, businesses, and consumers. An example of the government initiative includes the plastic packaging tax in the UK which means that businesses will have to pay either the penalties or meet the material requirements. The tax will be on the production and import of plastic packaging with less than 30% PCR (post-consumer recycled) content. To meet the growing demand, KM Packaging has launched PCR product solutions across different ranges, including (a) K peel - offering greater convenience with peelable lidding films, (b) K foil - the perfect partner for aluminium trays, and (c) K seal - a secure packaging solution that reduces the risk of leaks. All the product specifications that contain PCR meet the minimum of 30% content required to avoid the tax. The Plastic Packaging Tax will be charged at a rate of £200 per tonne, and some businesses may initially consider that to be more cost-effective than investing in PCR for their packaging. However, the actions of competitors, customer preferences, and corporate sustainability goals will influence when businesses consider the value of using PCR in their packaging (KM Packaging, 2022). In a similar initiative, the PM of New Zealand announced a target on banning hard-to-recycle plastic and polystyrene, potentially banning meat trays, cups, and takeaway food containers. Woolf (2019) anticipates that the Government would be banning fruit stickers and polystyrene, but some would like all plastics to be banned simultaneously. Various companies in NZ are also in sync with the government announcement on plastic. For example, Trower (2020) reports that Zespri NZ has committed to making all packaging 100% reusable, recyclable or compostable by 2025. They shared these commitments with growers, consumers, and suppliers at the kiwifruit conference (Momentum 2020: Standing Up & Standing Out). Zespri also committed that its plastic packaging will be made from at least 30% recycled plastic and by 2030, it will reduce its packaging footprint by 25% per kg of fruit produced. Carol Ward (Zespri CIO) says that today's consumers care about what their food is wrapped in, where it comes from, and whether it has been grown in an environment-friendly manner or not. Carol claims that 95% of our packaging used to transport kiwifruit to market is already cardboard, but there is more to do. Some of the actions undertaken by Zespri include reducing the weight of liners in cardboard transport packs, trialling fibre-based solutions for pocket packs, implementing improved recycling options, and eliminating all unnecessary packaging. Yet another report by Garrett (2022) claims that Yes! Apples new plastic bags (**Figure 6**) are made with 5% less plastic, while their new cardboard boxes are fully recyclable. Paper bags and cardboard boxes can be recycled kerbside, while plastic bags can be dropped off at the nearest soft plastic recycling location, usually at grocery stores.

Figure 6 Yes! Apple Plastic Bags
(*Source*: Garrett, 2022)

Merabtene *et al*. (2022) state that in the past few years, flexible packaging materials have received considerable interest and have experienced strong growth for fast-moving consumer goods (FMCG). For example, in 2019, the total sales of flexible packaging reached $228 billion which is estimated to be $269 billion by 2024. Flexible packaging applications include frozen food, pharmaceutical products, and cosmetic applications. The shelf-life of the product depends on the sealing integrity and the barrier properties of the flexible material. Several machines are used for the closure of flexible materials by applying heat and pressure toward the inner sealant layer of the film that gets partially molten, thereby wetting is achieved. Generally, product deterioration is caused due to seal failure.

2.5 Summary of the Literature Review

The above literature review and **Table 1** (below) will provide the readers with a significant sense of hope and optimism that so many different types of research activities and commercial practices are taking place globally in various sectors to make the overall business operations, distribution, supply chain and transportation move and progress toward the many shades of sustainable goals. In this context, **Table 1** is expected to serve as a quick recall of the various types of research activities including edible and biodegradable packaging materials and packaging practices adopted by different companies. Some of the interesting terms in the literature review include bio-based polymers, copolymerization process, intelligent packaging, Kano model, lean systems in packaging, shrink-wrap of produce, cardboard packaging, bioactive compounds, polyphenols, nanocellulose film, home-compostable stretch film, eco-fabrics, bio-pop, and PLU (price-look-up) stickers.

Table 1 Summary of the Literature Review

Sustainability initiator/researcher	Sustainability initiative idea(s)/researched topics
Reichert et al. (2020)	bio-based polymers belonging to the polyesters group are slow to biodegrade, and their structure needs to be modified through copolymerization or other techniques to accelerate their biodegradation.
Erika et al. (2020)	evaluated the perception of intelligent packaging in Slovakia through the Kano model and indicated that older consumers have a lower innovation but the highest need for packaging innovation, and they are not interested in all packaging functions.
Fitzgerald (2003)	smaller pack-houses in Nelson have ceased their operations due to increasing packaging costs, and increased variety of lines packed (based on size, variety, and colour of fruits).
Doevendans et al. (2015)	studied the extent to which lean systems are applicable and currently used within the NZ pipfruit industry and how they could be implemented in packhouses.
Chapman (2019)	concerned that vegetable supplies will not be sustainable with future population growth, and there is a need to grow commercial vegetables for the domestic and export markets in NZ.
T & G Annual Report (2015)	the largest number of NZ seasonal workers from the Pacific Islands get employed under the RSE scheme in the horticulture and viticulture industries.
Tenge-Rietberg (2019)	increased bureaucracy, labour shortage, and increased labour costs motivate farmers and traders towards automation to save the workforce or use them efficiently. For example, automation is becoming popular in fruit picking, asparagus peeling, and other processes, adding more value and cost-efficiency.
Stauffer (2019), McGregor (2019)	argue that shrink-wrap of cucumber in polyethene may improve its shelf-life from 3 days to 14, but the plastic wrap will last more than a century and probably end in the oceans. Of the 78 MT of plastic packaging produced each year globally, only 14 % (10.92 MT) gets recycled, while 9 MT escapes the collection annually.
The Dutch company Argos Packaging	launched a sustainable cardboard packaging made from locally grown elephant grass with no pesticides, irrigation or fertilizers. A plot of elephant grass absorbs four times more CO_2 than the same size of planted trees.
Delphine (2020)	emphasizes the usage of 100% recyclable cardboard packaging with two advantages: (i) openings in cardboard (Fig 2) make apples visible to customers, and (ii) are unlikely to be removed as long as the packaging remains intact.
McGregor (2019)	reports that the battle against plastic in the fresh produce industry has intensified. Most supermarkets are charging for plastic bags.
(McGregor, 2019 & Vroode), Stauffer (2019)	indicate that users favour the use of plastic packaging as it protects food from bacteria, temperature, and light and allows growers, distributors and retailers to reduce food waste. Consumers like to see colourful, fresh produce; growers brand their products with additional selling features on the package, and retailers could charge per package rather than per kg.
Tim Newton	claims that all their punnets are 100% recyclable in the UK and contain 50-80% rPET (recycled plastic).
Berry World (2020)	packaging has reduced their use of plastic sporks from 57 tons to 7.2 tons annually. Further, reducing the thickness of some punnet formats has reduced plastic usage by 71 tons.
Dilucia et al. (2020)	are concerned that fruit and vegetable by-products are the most abundant food waste from edible oil, juice, wine, or sugar production processes. The residues from these processes are generally discarded or used as animal feed or composted, but they are a great source of bioactive compounds, including polyphenols, vitamins, and minerals.
Nora et al. (2017)	reported about 1.3 billion tons per year of food waste from the production stage to the consumer domain. They identified the potential utilization of seasonal crops, crop remains, and by-products of fruit and vegetable using technologies to convert waste into value-added products.
Doyle (2019)	reported that researchers at the University of NSW, Australia have developed a process to turn banana plantation waste into a nanocellulose film used in food packaging.
Ghislain et al. (2020)	reported that plant-based nanocellulose (NC) is a biodegradable, non-toxic material whose mechanical, rheological, and gas barrier properties are competitive compared to oil-based plastics.

Table 2 Summary of the Literature Review (Con't)

Sustainability initiator/researcher	Sustainability initiative idea(s)/researched topics
(Mestre, 2020)	report that *Gruppo-Fabbri* developed a home-compostable stretch film that combines biodegradability with transparency, elasticity, breathability, and mechanical resistance of plastic.
Cactus leather & pineapple-leaf wool (2020)	showcased eco-fabrics of the future that use plants and natural waste instead of artificial fibres. The displays included cactus leather, wool from pineapple leaves (from the leftovers at juice bars), and innovative sportswear embedded with live bacteria to neutralize the body's odour.
Antoinette Laird (Foodstuffs NZ)	reflects that stickers have helped identify the product correctly. However, they would be introducing fibre-based packaging options for produce, which are home compostable. Further, bananas will be without wrappings preventing about 19,000 tons of plastic from going to landfills every year.
Santorromán (AFCO President)	stresses that environmental impact and economic life cycle costs are significantly lower for cardboard containers than reusable plastic ones. Some exporters are concerned that cardboard packaging could lose its competitiveness in long-distance refrigerated transport. However, if quality standards are achieved, the cardboard box will be perfectly adequate.
Scurria (SCF Packaging, 2020)	SCF is the first company to produce low-thickness packaging solutions called *Biopop* (Fig 5) which is shock-absorbent and 100 % compostable in 4 weeks. *Biopop* may be the future option as punnets, trays, containers of all kinds can be disposed of with organic waste.
Woolf (2019)	the Government could ban fruit stickers and polystyrene, but some would like all plastics simultaneously prohibited. The PM of NZ announced a target on the 'hard-to-recycle plastic & polystyrene' - potentially banning meat trays, cups, and takeaway food containers.
Nemat et al. (2020)	argued that clever packaging design could allow easy and proper sorting or separation. They concluded that food packaging design based on user-centred needs could affect consumer decisions on properly sorting packaging waste, enabling improved material recovery. The design should focus on the package's visual attributes, material selection, and waste sorting-related functions.
Konstantoglou et al. (2020)	conducted exploratory-factor analysis (EFA) of the packaging items which resulted in seven factors, including informational content, content protection & recognition, competent functioning, geometry, environmental friendliness, endurance, and colouration. The findings were informed by the consumer attitudes and predispositions towards packaging, thus having practical managerial applications.
Angie Skerrett (2019)	reports that PLU (price-look-up) stickers are necessary for the checkout staff to identify the fruit quickly, but they contribute to plastic. Bostock NZ conducted a trial of compostable PLU stickers for its apples to mitigate this problem, and the trial was successful. More compostable stickers will be rolled out to the European, US and NZ markets. The company would prefer not to use stickers, but many customers and retailers require them because they would not quickly identify organic apples from conventional ones without stickers

Despite many challenges, the die-hard terminators of plastics (as discussed next) are making immensely commendable efforts toward environmentally sustainable packaging.

3. THE DIE-HARD TERMINATORS OF PLASTICS AND SOME CHALLENGES

The 'plastic problems' globally have been documented throughout the last decade, with 2020 seen as the year of change. The food industry is often the first in the firing line to make some of the most significant changes. Packaging over the last decade has achieved quite a lot, but it is becoming common to neglect some of the learnings already established. For example, in the summer of 2019, Morrisons announced doing away with the plastic wrapping on cucumbers during the British growing season, saving 16m plastic sleeves. However, cucumbers without the plastic wrapping were expiring two days earlier than the wrapped ones. Morrisons continued going plastic-free despite protests from the Cucumber Growers Association and environmental groups concerned about increasing food waste. Similarly, Iceland promised to ditch 97% of its plastic use in Christmas packaging and remove plastic packaging from its products by 2023. Tesco is removing 1 billion plastic items from its stores by 2020, and Asda planned to reduce the amount of plastic in its own-brand packaging by 15% by Feb. 2021 and increase recycled plastic content in packaging by 30%.

Addressing the debate on whether to choose recyclable cardboard containers or reusable plastic ones, Santorromán (AFCO President) stresses that environmental impact and economic life cycle costs are significantly lower for cardboard containers than reusable plastic ones. Some exporters have apprehension that cardboard packaging could lose its competitiveness in long-distance refrigerated transport, but Santorromán feels that if the rules and quality standards are maintained then the cardboard box will be perfectly adequate.

There are, however, some challenges in the path of eradicating plastic packaging. A survey suggests that consumers are willing to pay 5-10 pence more per pack for environmentally friendly packaging. However, while there is an appetite for changes in packaging - shoppers are still not fully prepared to pay for such changes (The packaging challenge, 2020). Another challenge is the stickers on the fruits or products. According to Antoinette Laird (Foodstuffs NZ), stickers have helped staff and consumers identify the product correctly. However, they would be

introducing fibre-based packaging options for produce, which are home compostable. In addition, bananas will also be without wrappings, preventing about 19,000 tons of plastic from going to landfill every year (Cactus leather & pineapple-leaf wool…, 2020).

For products such as potatoes and carrots, the use of paper extends their shelf-life by protecting them from exposure to sunlight which reduces oxidation. As per Smith (2020), the demand for packaging has increased during the Covid-19 pandemic, and paper packaging is safer than plastic because the virus can live longer on the plastic surface than on paper. Similarly, Stefano Giusti (VP, Global Packaging for AFC) admires paper for its recyclability and sustainability as it can be recycled and reused up to seven times, and with the infrastructures in place for recycling, about 80% of all paper products would be recovered and fully recycled. Unfortunately, from a functional perspective, paper is not an ideal packaging option. So, to increase its functionality, the companies generally add coatings, and adhesives, and laminate them which hinders the paper package's recyclability. However, there is a solution created by AFC which is called 'NoWaste' (NoW) technology. While recycling, NoW separates from the paper, the pulper process, and leaves all the paper fibres to be recovered without any damage and without creating extra steps for the recycler (Smith, 2020).

Citing a specific example, Voorde (n. d.) adds that the demand for less plastic comes from Belgian consumers because the plastic issue is crucial for them. However, working without packaging was not always desirable. For example, Delhaize trialled 'pick & mix' tomatoes without packaging, and the sales volume decreased because many customers perceived that it was unhygienic when another customer touched the tomatoes. However, surprisingly, the sale of citrus fruits without packaging went up.

There are some points which favour the use of plastic packaging. For example, the plastics used in the fresh produce industry prolong the shelf-life of the produce by several days or more, so reducing plastic increases food waste, so there is a trade-off between 'increased food waste' and 'reduced plastic packaging' (McGregor, 2019 & Voorde, N.D). Stauffer (2019) also supports the above views by saying that plastic protects food from bacteria, temperature, and light and allows growers, distributors, and retailers to reduce food waste. Consumers can also see the colourful, fresh produce they purchase; growers can brand their products by adding additional selling features, and retailers can charge per package rather than per kg and offer convenience items like ready-made salad bowls and precut veggies. Citing a specific example, Siahaan and Purwanto (2022) reported that storage using plastic crates and cardboard was almost equally good at maintaining the hardness of chilli. However, in terms of maintaining the moisture content of chilli, plastic crate packaging was better than cardboard packaging.

4. DISCUSSIONS, CONCLUSIONS, AND RECOMMENDATIONS

It is noted from the above discussions and literature review that many efforts are directed toward sustainable packaging in various sectors of the economy including manufacturing, horticulture, foodstuff, and retail.

a. On-going Sustainable Packaging Practices

There are many examples of sustainable packaging and design practices undertaken by many companies, researchers, and innovators worldwide. There are also visible policy changes adopted in the functioning of the Government in different parts of the world, and there are also some visible attitudinal changes taking place in consumers toward the adoption of cardboard or paper packaging. However, while there is an appetite for changes in packaging materials toward sustainability, users and shoppers are still not fully prepared to pay for such changes.

Sharma and Singla (2021) report that manufacturing companies are adopting more environmentally friendly and greener practices by adopting the best possible ways from procurement of raw materials to the supply of finished goods to the end-users by evaluating and selecting the suppliers on sustainability criteria. This sustainability-centric approach enhances the firm's productivity in a resource-constrained environment. The paper recommended that top managers must incorporate best practices in sustainable supply chain operations to attain effective levels of business performance. The implementation of sustainable supply chain practices would contribute toward the optimal utilization of resources to enhance the corporate social responsibility (CSR) image towards waste minimisation and environment friendliness.

Anderson *et al*. (2020) studied the impacts of environmental and socially responsible activities on the financial performance of firms before and after the 2008 recession at different stages of the supply chain in four industries including retail, wholesale, manufacturing, and transportation. They found that the financial impacts of the CSR activities in supply chain firms have been fluctuating since 2008, however, in the retail industry, CSR activities have consistent positive impacts on profitability. Although the negative environmental activities have negative financial impacts on companies across all supply chain industries, it is just the opposite in the transportation industry where negative social activities are consistently associated with positive financial impacts.

b. Challenges in Sustainable Packaging

While people are shocked to see the frequent imagery of wildlife crippled or killed by discarded packaging not every consumer is prioritizing saving the planet ahead of their fresh choice of produce. The challenge ultimately lies with the food industry to innovate their packaging materials to ensure they are biodegradable, recyclable, sustainable, and affordable. Of course, that is easier said than done, but changing consumers' awareness of sustainable packaging and perceptions to accept some short-term costs for long-term gains provides a significant degree of optimism.

Although there are many challenges related to operational and transportation issues, the pack-houses, consolidators, logistics providers, and retailers are all set to deliver the freshest produce to the consumers. However, it is not practical or possible to suddenly do away with all the

products' packaging because consumers still want to enjoy the convenience of fruit- or food packaging.

García-Arca *et al*. (2020) propose that future research integrate packaging design with product design. For example, the integrated approach at IKEA has provided promising logistics efficiency and sustainability results. However, they also anticipate that the packaging function will become more complex due to the deployment of e-commerce and the omnichannel approach. At the same time, researchers are working on 'smart boxes' that could be filled, handled, warehoused, and transported (maybe automatically) to integrate efficiently into the load units using shared installations and open networks. In an attempt to take the integration to another level, Boldizsár *et al*. (2022) studied the possibilities of developing modular packaging machines for integrated data analysis and optimization based on artificial intelligence. A modular packaging technology will enable fast and flexible customer service, and combined with Industry 4.0, it can offer a solution to the logistics and production challenges of the future in this field.

c. Implementation and Adoption of Sustainable Packaging

Some researchers have expressed their opinions on how consumers (Palsson & Sandberg, 2020; Boz *et al*., 2020) are likely to react to the adoption of sustainable packaging. For example, Boz *et al*. (2020) stressed the importance of effective communication on sustainable packaging with consumers. They added that many sustainable alternatives might not be implemented if food packaging suppliers and companies are directed only by consumers' opinions on sustainability. This is because consumers do not always select the most sustainable package. However, if food packaging companies employ proven sustainable packaging and communicate with consumers effectively, it will be embraced. Expressing a bit similar view on the adoption of sustainable packaging, Palsson and Sandberg (2020) opine that to minimise the environmental footprint of packaging in supply chains, internal and external collaborations are necessary. They further add that different materials communicate different levels of sustainability to consumers, which may not be in line with life cycle assessment outcomes. Therefore, even though consumers hold positive attitudes toward sustainable packaging, it should not be assumed that they will readily make the right environmental choice.

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