Gazi Mühendislik Bilimleri Dergisi
2020, 6(2): 129-137
Derleme Makalesi/Review Article
https://dergipark.org.tr/gmbd

Kağıt Esaslı Ambalajlarda Sürdürülebilirlik

Bekir KESKİN[*,a], Bilge Nazlı ALTAY[b], Abdullah KURT[c], Paul D. FLEMING[b]

[a,*] *Ankara Hacı Bayram Veli University, Printing and Publishing Technologies, 06500, ANKARA, TURKEY*
[b] *Western Michigan University, Chemical and Paper Engineering, 49008-5462 , KALAMAZOO, MI, USA*
[c] *Gazi University, Manufacturing Engineering Department, 06500, ANKARA, TURKEY*
[b] *Western Michigan University, Chemical and Paper Engineering, 49008-5462 , KALAMAZOO, MI, USA*

MAKALE BİLGİSİ

Alınma: 20.07.2020
Kabul: 15.08.2020

Anahtar Kelimeler:
sürdürülebilirlik,
çevre dostu, malzeme,
kağıt, ambalaj

Sorumlu Yazar:
e-posta:
bekir.keskin@hbv.edu.tr

ÖZ

Sürdürülebilirlik çevreyi, doğal kaynakları ve gelecek nesillerin yaşamlarını etkin bir şekilde korumak için atılan adımların toplamıdır. Mevcut kaynakların verimli kullanımı ve doğanın korunması, artan nüfus ve üretim, küresel ısınma ve kentleşmenin olumsuz etkisini azaltmak için yaşamın tüm alanlarında kullanılabilecek önemli bir yaklaşımdır. Kağıt esaslı ürünler, yenilenebilir bir kaynak olması, ucuz, hafif, dayanıklı bir malzeme olması ve doğada kolayca bozunması sebebiyle üreticiler ve kullanıcılar tarafından tercih edilmektedir. Ambalaj endüstrisinde de diğer tüm üretim ve tüketim alanlarında olduğu gibi, çevresel etkileri en aza indirmek için çeşitli adımlar atılmaktadır. Bu çalışmada sürdürülebilirliği artıran mevcut eğilimler ve yöntemler ele alınmıştır. Kağıt esaslı ambalajların malzeme özellikleri, karbon ayak izleri, sosyal yönleri ve geleceği genel çerçevede tartışılmıştır.

https://dx.doi.org/10.30855/gmbd.2020.02.05

Sustainability in Paper Based Packaging

ARTICLE INFO

Received: 20.07.2020
Accepted: 15.08.2020

Keywords:
sustainability,
environmentally
friendly, material, paper,
packaging

Corresponding Authors
e-mail:
bekir.keskin@hbv.edu.tr

ABSTRACT

Sustainability is the sum term of the steps taken to protect the environment, natural resources, and the lives of future generations effectively. The efficient use of available resources and protection of nature is an important approach in all areas of life to decrease the negative effect of increasing population and production, global warming, and urbanization. Being a renewable resource, cheap, lightweight, durable material and the ease of degradation in nature enable paper based products favorable by users. As in all other production and consumption areas, some steps are taken in the packaging industry to minimize the environmental impact. Here we report the current trends and methods that increase sustainability. The material properties, carbon footprints, social aspects, and the future for paper based packaging are discussed in the general framework.

https://dx.doi.org/10.30855/gmbd.2020.02.05

1. INTRODUCTION *(GİRİŞ)*

Industrial advancements drive big changes and developments in production methods, machinery, mechanization systems and automation, society, social life and life styles. These advancements have accelerated mass production capacity, while population growth has increased the consumption rate. The expanded impact of urbanization, intensive industrial production and excessive consumption of natural resources have emerged as a precursor of great problems for the future [1].

Sustainability is defined as a possible way of life for individuals, companies, governments and other institutions to act responsibly by sharing the ecological resources that humans and other creatures share, as if they own the future [2]. Awareness of global warming, carbon emission footprint, high rate

Bu makaleye atıf yapmak için: B. Keskin, B.N. Altay, A. Kurt and P.D. Fleming, "Sustainability in Paper Based Packaging," *Gazi Journal of Engineering Sciences*, vol. 6, no. 2, pp. 129-137, August, 2020, doi: https://dx.doi.org/10.30855/gmbd.2020.02.05.

of consumption and its effects on the natural resources have triggered behavioral changes worldwide, and have invited people to be mindful on their duties and responsibilities in the production and consumption ring. In this regard, using available natural resources efficiently and protecting environment requires production of goods with renewable resources and methods rather than unsustainable fossil fuel resources [1,2]. Countries, companies, stakeholders and individuals have started to show sensitivity on issues such as conservation of natural resources, reuse, recyclability and sustainability. Thus, the benefits of economic, social and environmental achievements are inevitable to entitle products and production methods as sustainable (Figure 1).

Figure 1. The effect of sustainability actions on other fields *(Sürdürülebilirliğin diğer alanlara etkisi)*

An undeniable product at every stage of our lives is packaging. It contains, protects, preserves, transports, informs and sells in many countries and it is fully integrated into business, industrial, and personal use (Figure 2). It is already an important export item for countries and has a great potential for future. With the developing technology and increased utilization of products, the need for packaging increases every day, especially in times of pandemic we are facing today where web sales grow 76% in June [3]. The more packaging is used, the more it creates production needs worldwide and various trends. Some of the global trends such as increase in customer health awareness, sustainability, environmental concerns, recycling, digitalization and internetization have been reported [4]. For the regional trends, the ease of use and functionality, small packaging size, low portion, suitable packaging for urbanization and intense lifestyle, designs that facilitate fast consumption, aesthetics and discernibility have been encountered [5,6].

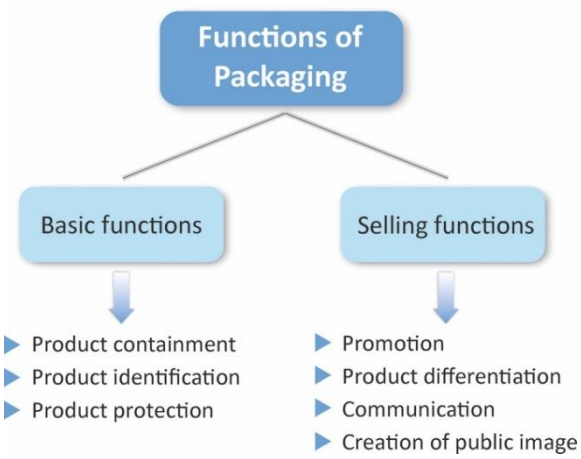

Figure 2. Functions of packaging *(Ambalajın fonksiyonları)*

Using recycled packaging materials, reusable green packaging and biodegradable packaging materials are the methods of achieving sustainability in packaging [5]. Recycled packaging materials may include molded pulp, corrugated cardboard, cardboard, newsprint paper, aluminum, steel, glass, and some plastics. Materials such as wood, plastic and metal, bulk and hand containers, boxes, shelves may be considered in the reusable green packaging class. Biodegradable polymers are materials that promote self-degradable of packaging in nature.

1.1. Market Size *(Pazar büyüklüğü)*

According to worldwide market reports and research authority in packaging, print and paper industries, the value of global packaging industry is estimated to be USD 1.2 trillion by 2028 listing the trends of sustainability, demographic and economic growth, consumer and brand owner trends would affect the future of packaging industry [7,8]. In the market, the paperboard packaging market was listed to be around USD 300 billion, of which 50% is made from wood based fiber. The value of non-fibre based packaging, such as plastic, glass and metal packaging was predicted to be USD 460 billion, being slightly more than half of the total packaging market (Figure 3). Between 2018 and 2028 the global packaging market is expected to expand by almost 3% per annum, reaching over $1 trillion in 2023 and $1.2 trillion in 2028 [8]. Global sustainable packaging market was around 220 billion dollars in 2018, this figure is expected to reach 280 billion dollars by 2025 and increase with a compound annual growth rate of ~6% [9].

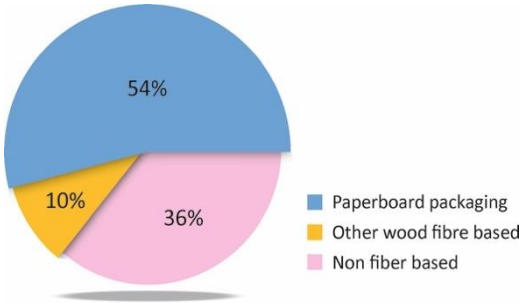

Figure 3. Packaging market share *(Ambalaj pazar payı)* [***Hata! Yer işareti tanımlanmamış.***]

2. SUSTAINABILITY IN PAPER BASED PACKAGING INDUSTRY *(KAĞIT ESASLI AMBALAJ ENDÜSTRİSİNDE SÜRDÜRÜLEBİLİRLİK)*

Sustainability is achievable in many different ways. Using 100% recycled materials or raw materials, minimizing the carbon footprint during production, transportation and consuming, reusing, extending the life cycle of packaging while creating a circular economy helps to get a sustainable process. If the sustainable packaging needs to be defined, the most sustainable packaging is the packaging that never existed. However, since this definition cannot go beyond being a utopia, a definition that is compatible with reality is required. According to the Sustainable Packaging Coalition (SPC) sustainable packaging [10]:

• is useful, safe, and healthy for individuals and communities throughout its life cycle,
• meets market criteria for performance and cost,
• is supplied, produced, transported, and recycled using renewable energy,
• optimizes the use of renewable or recycled source materials,
• is produced using clean production technologies and best practices,
• is made from healthy ingredients throughout its life cycle,
• is physically designed to optimize materials and energy
• is effectively recycled and used in biological and/or industrial closed-loop systems [10].

Another organization, the Sustainable Packaging Alliance (SPA) that works on sustainable packaging defines packaging as [11]:

- *Effective:* "Reduces product waste, improves functionality, prevents over packaging, reduces business costs, achieves a satisfactory return on investment "
- *Efficient:* "Improves product/packaging ratio, improves energy, material, and water efficiency, increases recycled content, reduce waste to landfill"
- *Cyclic:* "Returnable, reusable, recyclable, biodegradable"
- *Clean:* "Reduces airborne, waterborne, and greenhouse gas emissions, reduces toxicity and litter impacts".

The sustainability in packaging encompasses everything from design to production, consumption and destruction and should influence decisions both in the production process and in the materials used [12]. The factors that promote sustainability in the packaging industry include consumer brand perception, competitive pressure in the sector, environmental advocates and company culture. The methods that can be used to achieve sustainable packaging are [9]:

- *Recycle;* use of packaging materials that can be recycled and used in the production of new products.
- *Reuse;* return, refill; designing the packaging for multiple uses
- *Reformation;* as an alternative to non-recyclable materials, recyclable and sustainable alternative materials can be used to redesign the packaging.
- *Reduce;* reducing dimensions and amount of material to reduce packaging waste.
- *Renew;* using renewable materials for a cyclical production process and economy *[9]*.

Apart from its writing and storing information function, paper has been produced and used for packaging applications for centuries. Paper and cardboard materials are the most used packaging materials (Figure 3) and there are different thicknesses, structures and applications according to their usage areas. Cardboards are formed by combining paper of different thicknesses. Carton or cardboard is produced in a multilayer structure, mainly to meet the requirements of different products in a most economical and environmentally friendly manner. These materials have more advanced properties than paper. The multilayered structure can also be coated or laminated with chemicals to improve the wettability, barrier, flexibility, or structural

resistance properties [13]. The most common application of paper and cardboard is secondary packaging. Corrugated cardboard is used to transport everything from electronics to fragile glassware and perishable goods for industrial and residential use; packages for convenient storage and display of cardboard, food, medicine, and toiletries; paper bags offer customers a sustainable option to take home the products they bought; and paper shipping bags are often used to pack and ship bulk materials such as cement, animal feed, or flour. They can be designed to be sturdy and lightweight and can be used in different formats to meet product, industry or customer-specific needs by adjusting the appearance and print quality that greatly affect consumer preferences [14,15].

Plastic materials were firstly welcomed as a revolutionary material, as they are cheap, durable and light. Today, the thoughts on it have changed drastically, due to the effect on the environment and wildlife. In 2018, the British Statistical Institute announced that 90.5% of the plastic used during the year was never recycled [16]. Marine plastic pollution has become one of the most serious environmental problems in the world. Environmentally sensitive businesses, communities and even countries all over the world are increasingly banning disposable cases, especially plastic bags [17]. For the use of less plastic, precautions such as the sale of these packages were taken instead of giving them free of charge. Unlike paper bags that degrade on their own in nature, plastic bags remain around for 400 to 1000 years [12].

2.1. Sustainable Paper Based Packaging *(Sürdürülebilir Kağıt Bazlı Ambalaj)*

Paper basedPaper based packaging materials can be recycled and are biodegradable biologically in a short time. They are known as environmentally friendly and has the highest recycling rate among all packaging types. According to European Organization for Packaging and the Environment (EUROPEN), packaging suppliers should tell their customers how their packaging helps them achieve their corporate sustainability goals rather than talking about sustainable packaging [18]. The most important advantage of paper based packaging materials is the perception that they benefit all stakeholders and nature as a sustainable material. Trees or cellulose-derived plants are renewable resources through planned production and management. Consumers understand that fiber-based paper packaging is easy to recycle, as well as biodegradable. This perception creates the image that paper packaging is natural and exactly needed. Some sustainable effects of recycling paper based packaging:

- Paper based materials burn easily in incinerators. They can be used in bioenergy energy production instead of fossil-based fuels.
- Paper mills use their own waste/debris (shell and lignin) to produce more and more energy, so use of fuel is reduced.
- The forest industry and papermaking industry plant at least two trees for each tree they cut.
- Trees consume carbon dioxide and emit oxygen.
- The fiber can be reused four to seven times without fibers being too short to be recycled [19].

The most important environmental disadvantages associated with paper and cardboard use are;

- biodiversity loss due to tree loss and planting, soil erosion and basin imbalance,
- the effects of fertilizers used in growing trees,
- chemicals used in paper production and energy production,
- water used and emissions produced during the production [20].

Paper based applications in the packaging industry is growing to incorporate sustainable material usage. There are applications that utilize 100% recycled paper or new container designs, as presented in Figure 4, that minimize plastic usage [21].

Figure 4. Paper based sustainable packaging prototypes *(Sürdürülebilir kağıt bazlı ambalaj prototipleri)* [21]

2.2. Packaging Footprints *(Ambalaj Ayak İzi)*

Wide ranges of packaging materials are available in the packaging industry today. With the changing

lifestyles, expectations and needs, the consumption of packaging materials is increasing in almost all countries of the world. Increasing consumption also increases the environmental impact of the packaging industry. As the usage of glass bottles, cardboards, plastics, cans, corrugated boxes, etc. are increasing, the waste management problems are also increasing. The environmental impacts are directly related to the components such as raw material extractions, production, transportation and disposal of the packaging in the packaging industry (Figure 5), generating significant impact on the consumption of natural resources and pollution of nature [22]. Since packaging and the materials used in the production are important part of all areas of human life and cannot be removed from daily life, they need to be examined and analyzed to keep the environmental impact under control.

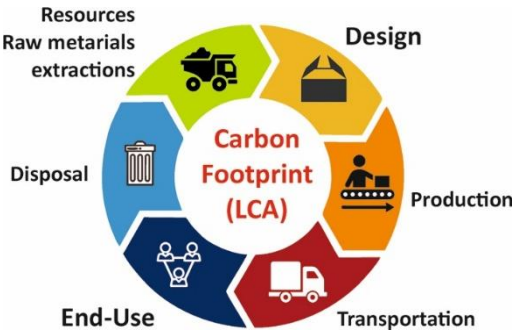

Figure 5. Typical impact assessment components *(Tipik etki değerlendirme bileşenleri)*

Life cycle assessment (LCA) is one of the quantitative methods to systematically estimate the environmental impact of the material and process used in packaging production. LCA uses different parameters, such as greenhouse gas (GHG) emissions, etc. (Table 1) associated with the production, consumption, destruction, or effects of a product throughout its life cycle. These analyses also include the evaluation of the energy and materials used during the life cycle of the packaging and the waste materials discharged to the environment. The technical framework of the LCA consists of four components that play an important role in the analysis. These are the goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment and life cycle interpretation [22,23] There are number of guidelines and standards help approaching carbon footprint analysis at the international and national level both for any organizations. ISO 16759 for instance sets guidelines for quantification and communication for calculating the carbon footprint of print media products (Table 1) [24].

Table 1. Greenhouse gases and global warming potentials (GWP) *(Sera gazları ve küresel ısınma potansiyelleri)*

Name	***Chemical formula***	***GWP for 100-year time period***
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	265
Hydrofluarocarbons	HFCs	100: 124 to 12400 (range)
Perfluorocarbons	PFC / FKW	6630 to 23,500 (range)

2.3. Sustainable Design *(Sürdürülebilir Tasarım)*

Packaging design is a complex process as all phases of the product, production, transportation and end use need to be considered. When sustainability is included, in addition to all these processes, design becomes more difficult and complex. Sustainability adds utilizations of environmental requirements, such as degradation time of the product, chemical impact on environmental life, the compatibility to the sustainability goals of governments or other organizations, the end-use, recycling or disposal of the product [25].

Some of the Sustainable design trends;

- design for recycling and reuse
- edible packaging (cups and wraps)
- replace plastics with paper (plastic out, paper in)
- shift to mono-materials
- increase recycled content
- life cycle thinking – reduce carbon footprint [26].

2.4. Sustainable Material *(Sürdürülebilir Malzeme)*

Sustainability mostly depends on the type of materials and the production. The prominent steps to increase sustainability in packaging are:

- reducing plastics and shrinking packaging size,
- increasing the use of innovative recyclable materials,
- reduction of material use and light material usage,

- reduction of material waste on production line,
- soy and vegetable-based alternative to petroleum based inks,
- advances in design and material substitution (including their converting and processing),
- enhancements in distribution and the consumer use phase,
- improvement to end-of-life processing,
- more paper based materials,
- awareness of consumer,
- research and preference of bio-based alternative materials [9].

Paper and paperboard are the most environmentally friendly and sustainable materials. Paper is more renewable and recyclable than other materials in the packaging industry. Paper based materials are suitable for sustainable design and lamination with other innovative alternatives to improve their properties. The use of lightweight and effective paper packaging would contribute to the reduction of packaging waste in nature. In this sense, the ecological footprint of the packaging is also reduced in nature. Paper based material helps to reach better consumer perception and brand positioning in the industry [9,18-19].

Paper and paperboard have limitations for some application areas such as oily and wet products. In these areas, to improve packaging properties paper based materials can be laminated with biobased plastic films to reduce petroleum based plastic usage and still have needed properties. Paper seems a good alternative for plastic, for this reason EU member states are going to ban the single-use of plastic because of its effect on the environment and wildlife [17].

2.5. Social Aspects of Sustainable Paper Based Packaging *(Sürdürülebilir Kağıt Bazlı Ambalajın Sosyal Yönleri)*

The problems in the fields of environment, production, the effects on natural resources and human life form an image about the type of packaging socially. Sustainability characteristics of paper and cardboard packaging also determine the position within the society. Sustainability is mostly a consumer driven trend but consumers do not understand what sustainability actually means.

There are behaviors expected from consumers regarding sustainability in paper based packaging. In this regard, checking the recycling information by checking the packaging and labels, seeking sustainable packaging, striving to inform people about sustainability, purchasing, and supporting these products by paying more for sustainable products are the most important ones. Two out of every three consumers believe that the companies that aim to produce sustainable packaging and their attempts in this regard are more reliable. The approaches of new generation customers in the field of packaging can be listed as follows:

- sustainable packaging preference by examining the labels of the packages,
- direct sustainable packaging preference,
- recommending sustainable and environmentally friendly products,
- can pay more to buy sustainable products
- 59% of consumers stated that they would pay more for sustainable packaging [9].

Survey data by IPSOS [27] reveal the popularity and image of paper packaging among users. These data support paper or carton that have the most sustainable packaging materials because of their benefits and properties. According to survey data on the paper and carton:

- 71% of customers think they are more likely to buy brands that package their products in paper or cardboard,
- 78% are more likely to buy products packaged in paper or cardboard than in other materials because they are better for the environment,
- 88% think paper based packaging is easy to open,
- 88% think paper based material is easy to recycle,
- 84% think paper is less wasteful than other packaging,
- 81% are more in line with today's expectations than packaging made from other materials,
- 83% agree that paper and cardboard packaging can be innovative,
- 63% would purchase products packaged in paper/cardboard so they can reuse the paper based packaging,
- 75% feel paper based materials allow more creative packaging designs than other packaging materials,
- 69% think products packaged in paper or cardboard seem more artisanal or handcrafted [27].

Generations of millennials and boomers are more sensitive to sustainability and environmental impact than other generations. Figure 6 presents the percentage of shoppers' feelings towards products that are recyclable, made with recycled and renewable materials, biodegradable, compostable and plant based [28].

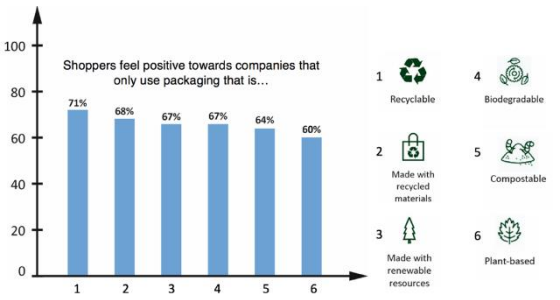

Figure 6. Customers' feelings towards sustainable packaging *(Sürdürülebilir ambalaja karşı müşterilerin yaklaşımları)* [28]

2.6. Future of Paper Packaging *(Kağıt ambalajın geleceği)*

Today, there is an average annual increase of 3.5% in the paper packaging industry. Sustainability studies and practices, the preference for lightweight and small packaging size will affect this growth. The increase in big metro-style markets instead of small markets, the fact that consumers turn to these markets due to cost, increase in the use of e-books, etc. reduce the use of papers. However, e-commerce popularity increases the use of brown corrugated cardboard paper. This rate is approximately 3.6%. Paper replaces plastic every day in the packaging industry. This change is currently ongoing. However, the answers to the questions of how and when this transition process will take place are complex. This change takes a long time. An increase is expected in the paper packaging sector, especially in the field of corrugated cardboard, for the next 10 years [29]. Thanks to digital platforms, sustainability-themed campaigns would be organized. Unnecessary resource consumption may be prevented by using more of the smart technologies. By providing the necessary information and guidance from the digital platforms, consumers will be educated to take the necessary steps for demanding increased sustainability. 93% of professionals working in the packaging industry stated that they believe that their customers' sensitivity towards sustainable packaging will increase [9].

3. CONCLUSION *(SONUÇ)*

Reuse, reduce, renewal, recycling and reformation methods help increasing sustainability in packaging. Paper based packaging is the most suitable material for all these methods. Besides recyclability, the biodegradability and eco-friendliness of paper based packaging increases its usage every day. The rate of recycling and collection for paper based products are the highest of any packaging material at 83% and 92.5%, respectively (Eurostat 2016). Paper based products can be recycled four to seven times or more and has the highest recycling rate among all packaging materials.

ACKNOWLEDGMENT *(TEŞEKKÜR)*

The authors would like to thank Çiğdem Kıncak Yaşar for designing the graphics. This paper was presented as an ongoing study in the International Symposium on Business & Economics 2020.

This study is supported by the The Scientific and Technological Research Council of Turkey 2214-A project.

CONFLICT OF INTEREST STATEMENT *(ÇIKAR ÇATIŞMASI BİLDİRİMİ)*

The authors reported no potential conflict of interest.

REFERENCES *(KAYNAKLAR)*

[1] N. Moussiopoulos, C. Achillas, C. Vlachokostas, D. Spyridi and K. Nikolaou, "Environmental, social and economic information management for the evaluation of sustainability in urban areas: A system of indicators for Thessaloniki," *Greece Cities*, vol. 27, no. 5, pp. 377–384, October, 2010, doi: https://doi.org/10.1016/j.cities.2010.06.001.

[2] J.R. Ehrenfeld, "Colorless Green Ideas Sleep Furiously: Is the Emergence of 'Sustainable' Practices Meaningful?" *Reflections;The sol journal*, vol. 1, no. 4, pp 34-47, June, 2000, Doi: 10.1162/152417300569935.

[3] K. Evans, "As pandemic pushes on, online sales grow 76% in June," *Digital Commerce*, Available: https://www.digitalcommerce360.com/article/corona

virus-impact-online-retail/. [Accessed: July 10, 2020].

[4] B. Keskin, B.N. Altay, A. Kurt, P.D. Fleming, "Sustainability and Paper Based Packaging," *International Symposium on Business & Economics 2020 (ISBE)*, 4-5 June 2020, Turkey, 2020. Available: http://is-be.org/Pages/70/140/PUBLICATION [Accessed: July 06, 2020].

[5] B. Keskin, B.N. Altay, M. Akyol, G. Meral, O. Uyar, P.D. Fleming, "Global Packaging Trends", *6th International Printing Technologies Symposium*, İstanbul, Turkey, 2018, pp. 483-503.

[6] EIC-PMMI Report, "Global Packaging Landscape: Growth, Trends & Innovations 2019", *Euromonitor International Consulting-Packaging Machinery Manufacturers Institute (PMMI)*, 2019.

[7] Smithers Pira Report, "The future of packaging: Long-term strategic forecasts to 2028", *Smithers Pira*, Available:https://www.smithers.com/services/market-reports/packaging/ [Accessed: June 3, 2020].

[8] Smithers Pira Report, "Four key trends that will shape the future of packaging to 2028", *Smithers Pira*, Available: https://www.smithers.com/resources/2019feb/future-packaging-trends-2018-to-2028 [Accessed: June 1, 2020].

[9] PMMI Report, "Packaging Sustainability: A Changing Landscape 2020", *PMMI The Association for Packaging and Processing Technologies*, Available: https://www.pmmi.org/report/packaging-sustainability-changing-landscape, [Accessed: June 10, 2020].

[10] SPC, "Definition of Sustainable Packaging Version 2.0", *Sustainable Packaging Coalition*, Available:https://sustainablepackaging.org/wp-content/uploads/2017/09/Definition-of-Sustainable-Packaging.pdf. [Accessed: February 20, 2020].

[11] H. Lewis, L. Fitzpatrick, K. Verghese, K. Sonneveld, R. Jordon, "Sustainable Packaging Redefined" (Version 3), *Sustainable Packaging Alliance*, Melbourne, Australia, pp. 26, 2007.

[12] W. Jedlicka, "Packaging sustainability: tools, systems and strategies for innovative package design", New Jersey, USA, *Wiley*, pp. VIII-X, 224-225, 2009.

[13] T. Anukiruthika, P. Sethupathy, A., Wilson, K. Kashampur, J.A. Moses, C. Anandharamakrishnan, "Multilayer packaging: Advances in preparation techniques and emerging food applications," *Comprehensıve Reviews in Food Science and Food Safety*, vol. 19, no. 3, pp. 1156-1186, April, 2020, doi: https://doi.org/10.1111/1541-4337.12556.

[14] C. Şahin, Z. Özomay, B. Keskin, "Evaluation of Weighting Pressure's Effect On Dot Gain in Newsprint Paper," *EJOVOC- Electronic Journal of Vocational Colleges*, vol. 3, no. 3, pp. 121-128, December, 2013.

[15] H. Holik, S. Lomic, "Handbook of Paper and Board", 2 Volume Set, Singapore, *Wiley-VCH*, pp. 823, 2013.

[16] Global Web Index Report, "Sustainable Packaging Unwrapped", *Globalwebindex*, UK, 2019.

[17] The Guardian, "European parliament votes to ban single-use plastics", *The Guardian*, 2019, Available: https://www.theguardian.com/environment/2019/mar/27/the-last-straw-european-parliament-votes-to-ban-single-use-plastics. [Accessed: July 16, 2020].

[18] G.L. Robertson, "Sustainable food packaging", (in: *Handbook of waste management and co-product recovery, Volume 2*), *Woodhead Publishing Series in Food Science, Technology and Nutrition*, pp 221-254, 2009.

[19] D. Twede, S.E.M. Selke, P. Kamdem, D. Shires, "Cartons, Crates and Corrugated Board (2. Edition)", Lancaster, USA, *DEStech Publications*, pp. 530-540, 555-556, 2015.

[20] K.Verghese, E. Crossin, M. Jollands, "Packaging Materials" (in *Packaging for Sustainability*), New York, USA, *Springer-Verlag London Limited*, pp. 224-230, 2012.

[21] Sustainable Paper Packaging Applications, *Ecologic Brands*, Available: https://ecologicbrands.com/eco-bottle/. [Accessed: May 15, 2020].

[22] A.Varun Sharma, H. Nautiyal, "Environmental Impacts of Packaging Materials", (in *Environmental Footprints of Packaging*), Hong Kong, *Springer Science+Business Media*, pp. 115-13, 2016.

[23] S.S. Muthu, Y. Li, J.Y. Hu, P.Y. Mok, "An Exploratory Comparative Study on Eco-Impact of Paper and Plastic Bags," *J Fiber Bioeng Inform* vol. 1, no. 4, pp. 307–320, March, 2009, doi: 10.3993/jfbi03200909.

[24] Global Warming Potencial, *Greenhouse Gas Protocol*, Available: https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf, [Accessed: July 10, 2020].

[25] H. Lewis, "Designing for Sustainability", (in: *Eds., K. Verghese et al. Packaging for Sustainability*), New York, USA, *Springer-Verlag London Limited*, pp. 41-106, 2012.

[26] S. Kieselbach, "Top 9 sustainable packaging trends", *Sphera*, Available: https://sphera.com/blog/top-9-sustainable-packaging-trends/. [Accessed: July 16, 2020].

[27] J. Scarborough, T. Cox, "Straw Wars: Plastic Reduction-a new battleground for Brand Reputation". *IPSOS*, Available: https://www.ipsos.com/en/straw-wars-plastic-reduction-new-battleground-brand-reputation. [Accessed: July 19 2020].

[28] 2020 Food and beverage sustainable packaging trends, *Evergreen Packaging*, Available: https://evergreenpackaging.com/wp-content/uploads/19-EVP-0127-2020-Trend-Whitepaper-1-24.pdf, [Accessed: July 19, 2020].

[29] NOA Packaging Industry Report, "Strategic European Corrugated Report - 2018 to 2028", *NOA Limited*, Oxfordshire, UK, 2018.

Bekir KESKİN

Bekir Keskin worked both full time and part-time as a lecturer in private and public universities. He completed his research on paper and printing science at Western Michigan University, in the Department of Chemistry and Paper Engineering as a visiting scholar, during his doctoral studies between the years 2017-2019. Currently, he works at Ankara Hacı Bayram Veli University as a lecturer in Ankara, Turkey. His research interests include paper, packaging, printing technologies, color management, and graphic-visual design.

Bilge Nazlı ALTAY

Bilge Nazlı Altay completed her PhD in the field of Paper and Printing Science in the Department of Chemical and Paper Engineering at Western Michigan University in 2018. Currently, she continuous her post-doctoral research studies on printed electronics and related topics at École deTechnologie Supérieure University and MiQro Innovation Collaborative Center (C2MI) in Montreal, Canada. Her research interests include flexible and printed electronics, paper and printing science, color management and analysis of interactions between inks and coating formulations and substrates.

Abdullah KURT

Abdullah Kurt is an Associate Professor at Gazi University and teaches Static, Dynamic, and Mechanics of Materials in the Department of Manufacturing Engineering. He completed his MS and Ph.D. in the field of Mechanical Education. He published more than 50 scholarly papers and he got scientific promotion awards and projects. His research interests are metal cutting, machinability, mechanics of metal cutting, analysis of cutting tool stresses, finite element method on metal cutting, simulation of machining, and mathematical modeling of cutting parameters.

Paul D. FLEMING

Paul D. Fleming with more than 20 years of experience, has worked both in the private sector and in the universities. He completed his MS and Ph.D. at Harvard University in the field of chemical physics. Currently, he teaches graphic and printing science at Western Michigan University, in the Department of Chemistry and Paper Engineering. He has more than 400 scholarly papers and several patents in the USA.