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Evaluating the Environmental Footprint of Food Packaging using Lifecycle Assessment

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I. Introduction

Food packaging is a coordinated system of preparing edible items for transport, distribution, storage, and sale at an optimal cost [1]. South Korea's National Statistical Office notes that nearly 30% of South Korean households are single-person households, and more than 50% of South Korean women work outside the home [2]. Moreover, 95% of South Koreans use smart-phones, and the rate of Internet purchases is increasing yearly. As Koreans don't have enough time to buy daily goods in the market, and more households in Korea deliver goods by activating online shopping, packaging waste has grown exponentially, and plastic packaging waste has risen 30% over the past five years.

It is relatively difficult to recycle packaging because it often is printed in brilliant colors, and plastic film labels are difficult to separate. Disposing of waste packaging has become a problem in South Korea. In 2017 the country enacted the Framework Act on Circular Utilization, which sought to facilitate recycling of food containers [3]. An assessment revealed that the use of composite materials and colored ink degraded the ability to recycle food packaging [4,5].

This study evaluates the environmental impact of colored ink on food packaging. To increase the representativeness of findings, we examine the packaging of ramen noodles, the 7th largest food and beverages sales ranking in Korea in 2015 [6]. Life cycle assessment (LCA) is the global standard established by ISO 14040:2006 and ISO 14044:2006 to analyze the impacts of a product across its lifecycle [7,8]. We employ it to evaluate the impact of ramen packaging from manufacturing to transportation. Our scenario analysis identifies main issues and predicted environmental changes.

II. Materials and Methods

a) Steps in manufacturing food packaging

Food packaging is produced in five stages: gravure printing, dry laminating, extrusion laminating, inspection, and slitting [9,10,11] (Fig. (1)). Gravure printing entails laying up to eight colors on oriented polypropylene (OPP) film (each color requires a separate printing). Hot air passes continuously over the packaging to dry the ink. Coated packaging film is made by dry or extrusion laminating. Dry laminating involves applying a coating solution to the colored surface and drying it in a chamber. Extrusion laminating consists of heating polyethylene (PE) film to about 300° and passing the packaging through an extruder to be re-coated. Laminated film is an output of extrusion laminating. Finally, the laminated packaging is inspected, slit, and distributed. Electricity is the primary energy for all processes, although steam processing uses liquefied natural gas (LNG). Boilers emit airborne CO_2, NOx, and SOx. Food packaging production does not generate wastewater because the process uses no water. However, printing causes waste ink, and slitting generates a waste film.

b) Lifecycle assessment

This study evaluates the environmental impact of food packaging produced in accord with ISO 14040:2006 and ISO 14044:2006 [7,8].

Author: SMaRT-ECO Consulting Firm, Seoul 06338, Korea.
e-mail: kohung@smart-eco.co.kr

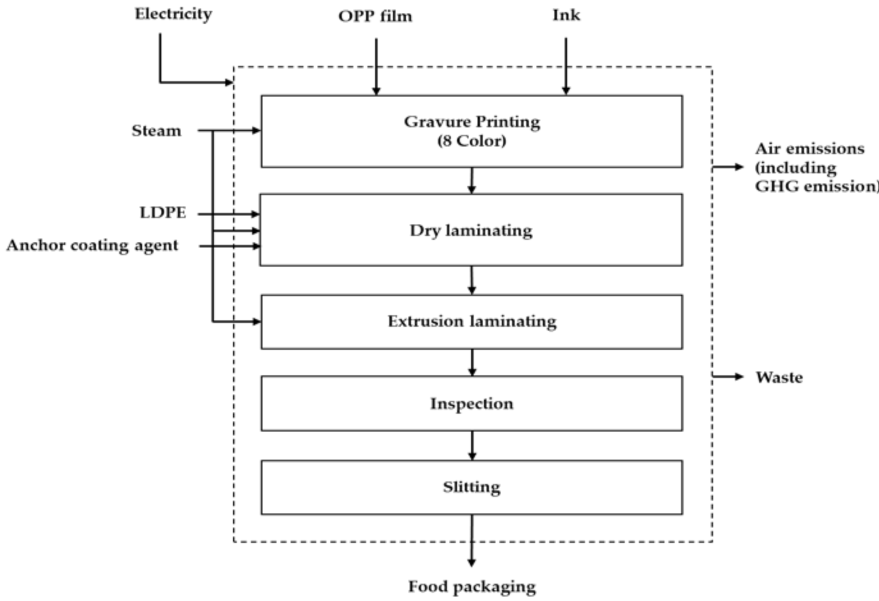

Fig. 1: Steps in manufacturing food packaging

Our reference unit is the quantified performance of a product system. We define the unit of analysis and reference flow per ECPEF guidelines (Table 1) [8,12]. Our functional unit is 1 m2 food containers printed with eight colors. The reference flow of 1 m2 food packaging is 60.84g. In Table 1, an eight-color container passes through eight printings, one for each color.

ISO 14044: 2006 defines a system boundary as criteria that specify what processes comprise a product system [8]. Since packaging is an intermediate product, the system boundary governing our collection of data spans "cradle to gate", as illustrated in Figure 2. Pre-manufacturing covers the production of material, film, and ink. Manufacturing involves gravure printing and making packaging film.

Table 1: Functional units in producing food packaging

Unit of analysis	Definition
Functions provided: What	Keep food safely
Extent of the function: How much	One packet of ramen printed in eight colors
Expected quality: How well	Packaging printed in sequence by nine sets of machines
Duration of product: How long	Not considered because packaging is an intermediate output

Our primary data are the inputs and outputs needed to manufacture food packaging. We collected data from a food packaging factory in Gwangju City over 12 months in 2016. Inputs include data for OPP film, low-density polyethylene (LDPE), ink, an anchor coating (AC) agent, electricity, and LNG. Output data include packaging film as a product, waste ink, waste film, and other industrial waste. Waste ink and film are industrial waste. We measured the quality of raw materials, ancillary materials, and product. To measure process quality (utilities, emissions, factory wastes), we converted factory-level data into product-level data. National waste statistics confirm that 67.4% of industrial wastes were recycled, 32% was incinerated, and 0.6% entered landfills [13].

We converted electricity and LNG used in gravure printing into product-level data per Eq. (1). Eq. (1) multiplies total inputs or output by the ratio of total manufacturing time to time needed to complete specific processes. Concerning gravure printing, time is the length of one print run divided by average printing speed. We calculated total printing time by multiplying the length of one printing roll by the number of prints. The number of print equals the number of colors on the packaging (i.e., printing five colors requires five print runs).

$$Converted\ input\ or\ output\ amount_{u_i} = Total\ input\ or\ output\ amount_u \times \left[\frac{\frac{i \times L_i}{V}}{\sum_{i=1}^{n}\left(\frac{i \times L_i}{V}\right)}\right]. \quad (1)$$

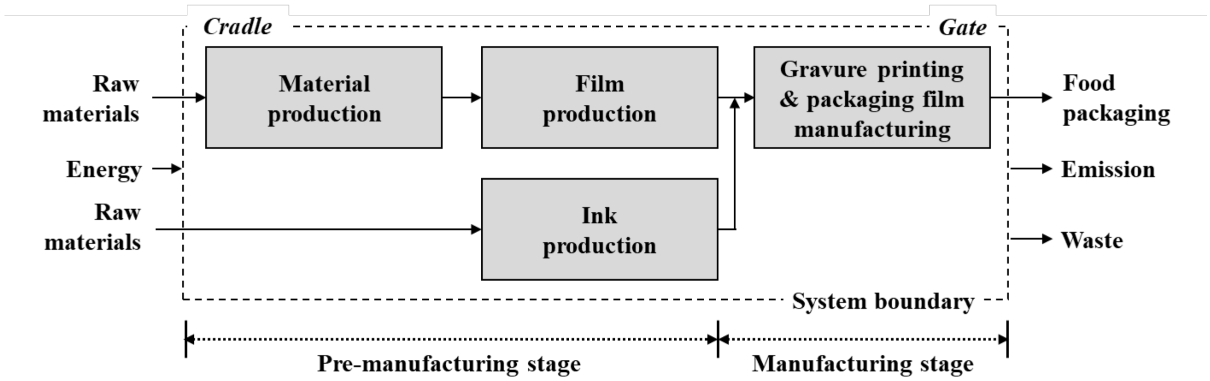

Fig. 2: System boundary for food packaging

In Eq. (1) *u* denotes process inputs (e.g., electricity, steam, or ink). *i* is the number of printings. *V* is the velocity of the gravure printer. *L* is the length of a roll of packaging film.

We calculated all inputs and outputs and converted factory-level process data into a product-level data by dividing the reference flow by the functional unit of production. Our results are called gate-to-gate (GtG) data.

Table 2 shows 2016 GtG data for manufacturing food packaging. It shows that yield in the packaging manufacturing factory was 95.1%. The Gwangju factory used 1.63 kWh of electricity and 0.13 Nm^3 of LNG to produce 1 kg of packaging. It produced 4.93E-03 kg of waste ink, 4.51E-02 kg of waste film, and 1.78E-03 kg of other wastes to make 1 kg of packaging. OPP film and LDPE are trucked from the Yeosu Petrochemical Industrial Complex in Jeollanam Province to the factory in Gwangju. Ink and glue are trucked in from nearby dealers.

Table 3 indicates the electricity and LNG used per unit of packaging. It depicts totals and four sub-processes: printing, dry laminating, extrusion laminating, and inspection & slitting. We applied the allocation in Eq. (1) to derive utility use per product to use per unit. Laminating consumed 82% of the electricity used, inspection & slitting 13%, and printing 5%. Laminating consumed the most energy because plastics are melted to coat printed packaging. Printing consumes little electricity.

Table 2: Gate-to-gate data for manufacturing food packaging

	Parameter name	Unit	Amount	Data quality	Source
Input	OPP film	kg	4.31E-02	Measured data	Annual production report (2016)
	LDPE	kg	1.45E-02	Measured data	
	Ink	kg	6.33E-03	Measured data	
	AC agent (Glue)	kg	1.08E-04	Measured data	
	Electricity	kWh	9.92E-02	Calculated data	
	LNG	Nm3	8.16E-03	Calculated data	
Output	Packaging film	m2	1.00E+00	Measured data	
		kg	6.08E-02	Measured data	
	Waste ink	kg	3.00E-04	Calculated data	
	Waste film	kg	2.74E-03	Calculated data	
	Industrial waste	kg	1.08E-04	Calculated data	

Table 3: Energy used per process in producing packaging film

	Unit	Total	Printing	Dry laminating	Extrusion laminating	Inspection & Slitting
Electricity	kWh/m2	9.92E-02	4.97E-03	4.69E-02	3.41E-02	1.31E-02
	%	100.0	5.0	47.3	34.4	13.2
LNG	Nm3/m2	8.16E-03	1.12E-03	8.80E-04	6.16E-03	
	%	100.0	13.7	10.8	75.5	

The Gwangju factory normally uses LNG to heat air for printed packaging and for molten plastic used in laminating. Laminating requires about 86% of LNG used and printing 13.7% (Table 3).

GtG data in Table 2 were compiled per results from the lifecycle inventory (LCI) using GaBi LCA software and the LCI database [14,15,16,17], which we selected to meet data quality requirements in the ECPEF guide (EC, 2013). Table 4 names the LCI databases, which are primarily developed by internationally accepted organizations such as Plastic Europe and Think step [14,15]. However, we constructed the LCI database for South Korean electricity because it was not available as internationally compatible International Reference Life Cycle Data [16].

Our lifecycle impact assessment (LCIA) evaluates potential effects on different environmental consequences using LCI results for food packaging [8,12,17]. The LCIA technical framework evaluates four procedures: classification, characterization, normalization, and weighting. We evaluate the environmental footprint of food packaging and compare it under alternative scenarios. Therefore we implemented the characterization and normalization steps to compare the normalized environmental footprint between impact categories. To do so, we adopted the LCIA methodology in the ECPEF guide [12].

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Table 4: LCI databases accessed for this study

No.	Parameter	DB Title (year)	Source
1	OPP film	Polypropylene film (PP) (2005)	Plastic Europe
2	LDPE	Polyethylene Low-Density Granulate (2017)	Plastic Europe
3	Ink	Paint emulsion (EN15804 A1-A3) (2017)	Think step
4	AC agent	Glue for gypsum boards (2017)	Think step
5	Electricity	South Korea Grid mix (2018)	SMaRT-Eco (this study)
6	LNG	Natural gas (2005)	Plastic Europe
7	Transport(Truck)	Transport, truck (2018)	Think step
8	Waste incineration	Waste incineration of plastics (2006)	ELCD/CEWEP
9	Waste landfill	Plastic waste on landfill (2017)	Think step

Table 5: Environmental consequences of food packaging

Impact category	Unit	Indicator results
Human toxicity (cancer)	CTUh	1.43 E-09
Human toxicity (non-cancer)	CTUh	5.57 E-08
Ozone depletion	CFC-11 eq.	1.49 E-10
Particulate matter	kg PM2.5 eq.	4.62 E-04
Ionizing radiation	kBq U235 eq.	2.64 E-02
Acidification	Mole of H+ eq.	5.79 E-03
Photochemical ozone creation	kg NMVOC eq.	2.69 E-02
Eutrophication (terrestrial)	Mole of N eq.	1.06 E-02
Eutrophication (freshwater)	kg P eq.	4.35 E-06
Eutrophication (marine)	kg N eq.	8.72 E-04
Eco-toxicity	CTUe	7.45 E-02
Water depletion	m3 eq.	4.41 E-02
Abiotic resource depletion	kg Sb eq.	4.30 E-06
Land use	kg (deficit)	3.92 E+00
Global warming	kg CO2 eq.	2.02 E+00

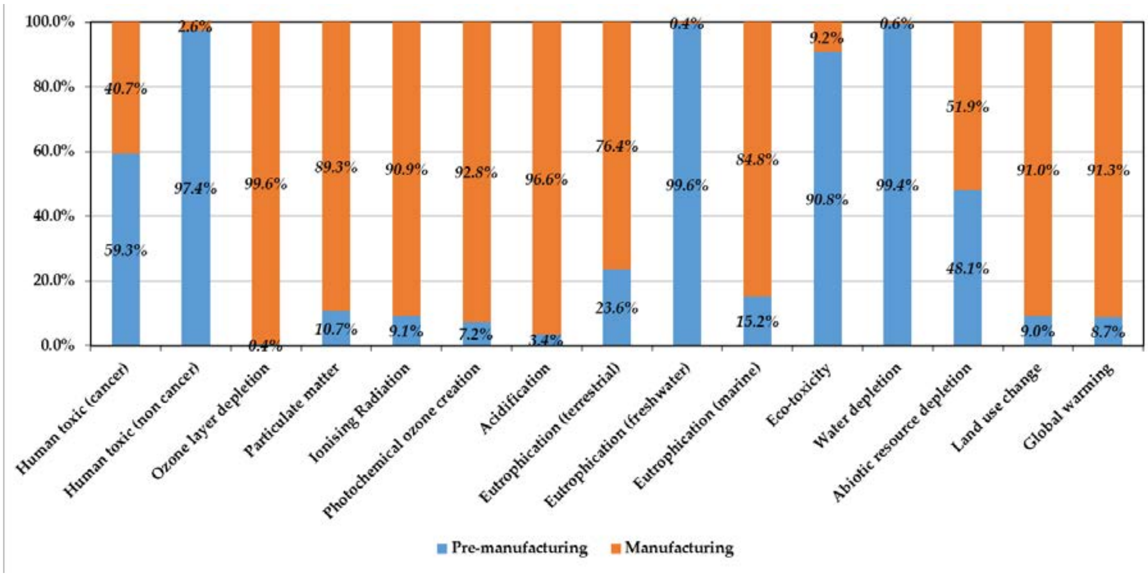

Fig. 3: Contribution of pre-manufacturing and manufacturing to 15 environmental consequences

II. Results and Discussion

a) *Measuring potential environmental impact*

We constructed an LCIA for food packaging using ISO 14044:2016 and the ECPEF guide [9,13]. Column 1 in Table 5 shows 15 categories of environmental consequences. LCIA results in the third column are impact category indicators in the characterization step; the second step in constructing an LCIA. The potential impact is 2.02 kg of $CO_{2\text{-eq}}$ on global warming and 4.41E-02 $m^3_{\text{-eq}}$ on water depletion. The impacts on human toxicity (cancer) and human toxicity (non-cancer) from chemicals (e.g., printing ink) are 1.43 E-09 CTUh and 5.57 E-08 CTUh. CTUh—Comparative Toxic Unit for Humans—indicates an estimated increase in morbidity throughout the human population per unit of an emitted chemical [19].

We analyzed the results of the 15 impact categories in three respects: lifecycle stages, unit processes, and activities. Figure 3 illustrates the cumulative results of two lifecycle stages for 15 environmental consequences. Impacts on global warming, ozone depletion, acidification, and photochemical ozone creation arise mainly from energy use. They accounted for more than 90% in the manufacturing stage of food packaging. The potential impacts on eutrophication and water depletion are dominant during pre-manufacturing because packaging stage consumes no water. The potential impact on human toxicity and eco-toxicity are dominant during pre-manufacturing, which involves the use of ink and plastic resin. Gravure printing emits a large quantity of volatile organic compounds from the ink into the workplace, but we disregarded their effects because LCA generally evaluates effects of emissions released externally.

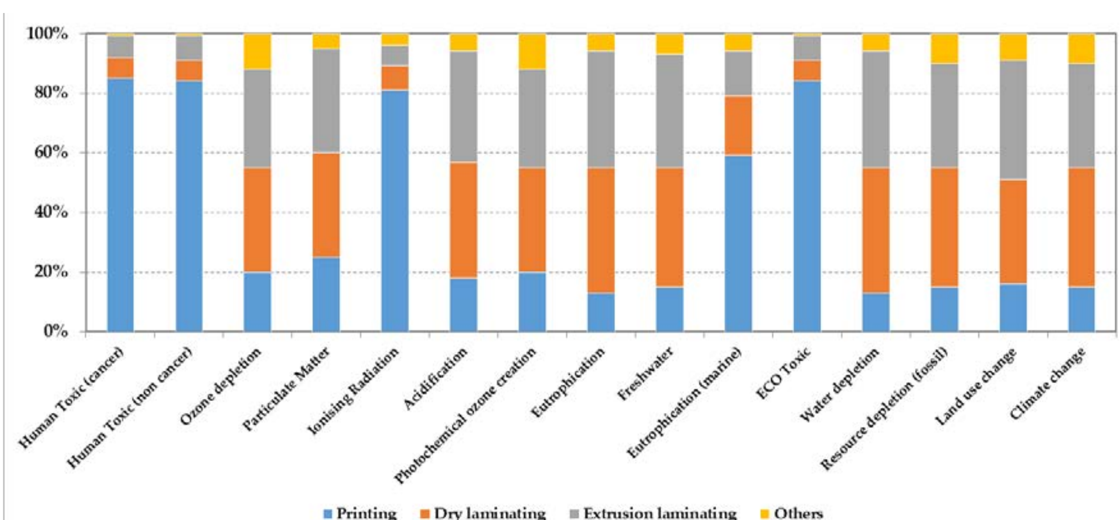

Fig. 4: Contribution of each unit process to 15 environmental consequences

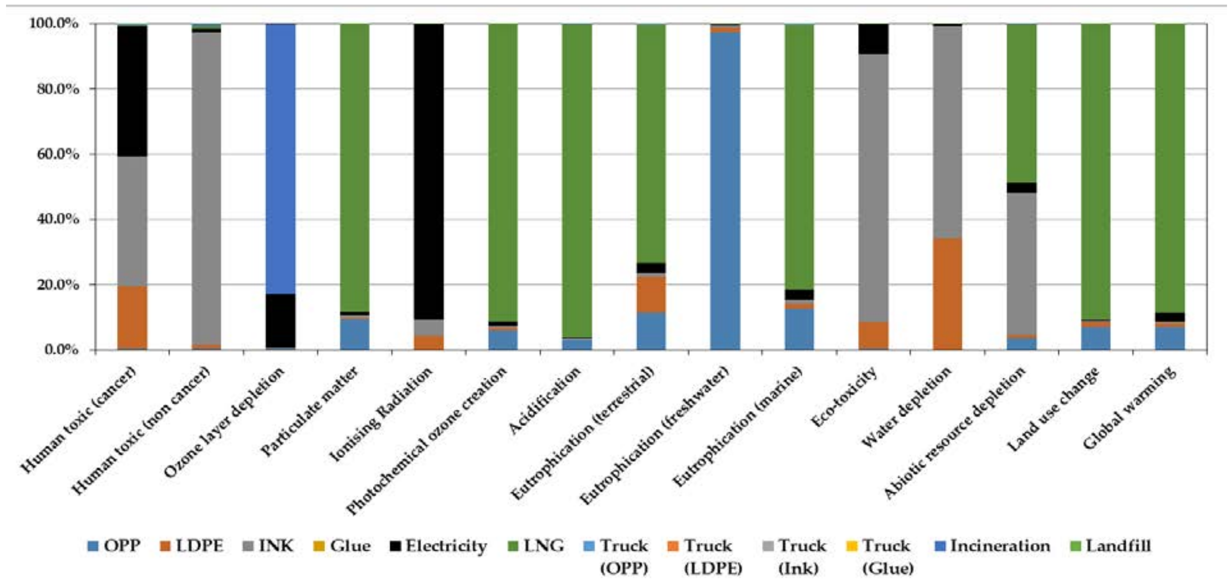

Fig. 5: Contribution per activity to 15 environmental consequences

Figure 4 shows the cumulative impact category indicator results of four unit processes on 15 environmental consequences. For easier category comparison, the four-unit processes sum to 100% for all categories. Printing contributed the most to human toxicity (cancer), human toxicity (non-cancer), and eco-toxicity. Manufacturing printing ink indirectly induces eutrophication. Use of electricity and LNG during laminating affects other impact categories.

Table 5 presents the cumulative effects of each packaging activity on each environmental impact category. "Activity" means inputs or outputs that can generate the indicated environmental impact. In Figure 4, manufacturing OPP film, LDPE, and ink dominated four environmental consequences: human toxicity (cancer), human toxicity (non-cancer), eco-toxicity, and water depletion. Use of electricity and LNG dominate the potential impact from particulate matter, ionizing radiation, photochemical ozone creation, acidification, eutrophication (terrestrial), eutrophication (marine), land use change, and global warming.

b) Measuring normalized environmental impact

In Table 5 units of measuring potential environmental impact differ. To identify the relative magnitudes of effect on each of the 15 categories, [8] Table 6 normalizes data from Table 5. Normalization [19] transformed results in a person-equivalent measure (PE). The main normalized impacts are acidification, water depletion, global warming, photochemical ozone creation, particulate matter, and human toxicity (non-cancer).

Figure 6 compares relative magnitudes for six categories of environmental consequences boldfaced in Table 6. Use of LNG contributes most to particulate matter, photochemical ozone creation, acidification, and global warming. Printing ink and LDPE film make the significant contribution to human toxicity (non-cancer) and water depletion. The effect of electricity was insignificant for all categories.

Table 6: Normalized category indicator results of food packaging

Impact category	Normalization Reference		Normalized results	
	Unit	Amount	Unit	Amount
Human toxicity (cancer)	CTUh/PE	3.69E-05	PE	3.88E-05
Human toxicity (non-cancer)	CTUh/PE	5.33E-04	PE	1.05E-04
Ozone depletion	CFC_{-11} eq. /PE	2.16E+02	PE	6.91E-09
Particulate matter	kg $PM_{2.5}$ eq. /PE	3.80E+00	PE	1.22E-04
Ionizing radiation	kBq U_{235} eq. /PE	1.13E+03	PE	2.34E-05
Acidification	Mole of H+ eq. /PE	4.73E+01	PE	5.69E-04
Photochemical ozone creation	kg NMVOC eq. /PE	3.17E+01	PE	1.83E-04
Eutrophication (terrestrial)	Mole of N eq. /PE	1.76E+02	PE	6.00E-05
Eutrophication (freshwater)	kg P eq. /PE	1.48E+00	PE	2.94E-06
Eutrophication (marine)	kg N eq. /PE	1.69E+01	PE	5.16E-05
Eco-toxicity	CTUe/PE	8.74E+03	PE	8.52E-06
Water depletion	m^3 eq. /PE	8.14E+01	PE	5.42E-04
Abiotic resource depletion	kg Sb eq. /PE	1.01E-01	PE	4.26E-05
Land use	kg (deficit) /PE	7.48E+04	PE	5.23E-05
Global warming	kg CO_2 eq. /PE	9.22E+03	PE	2.19E-04

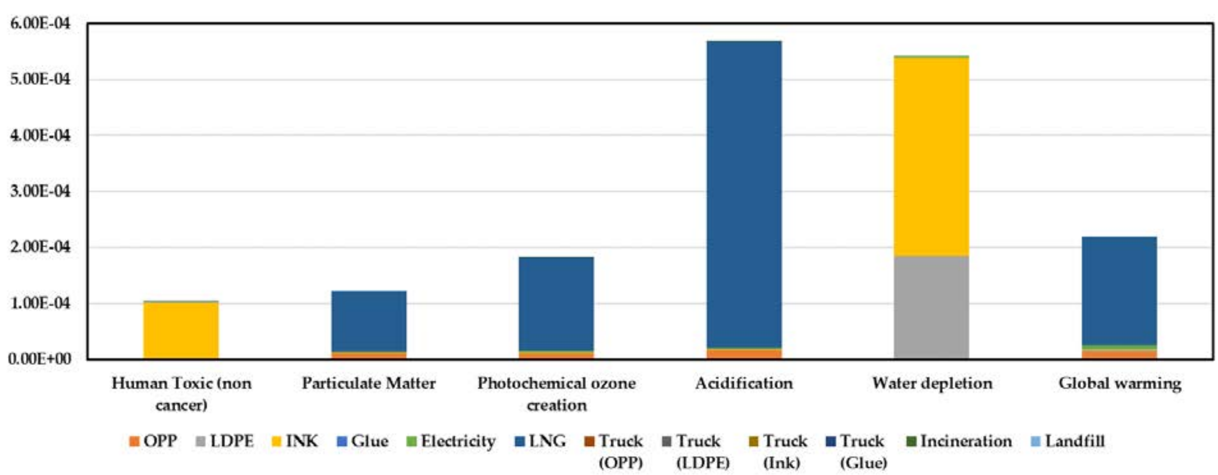

Fig. 6: Cumulative normalized impact of inputs on six environmental consequences

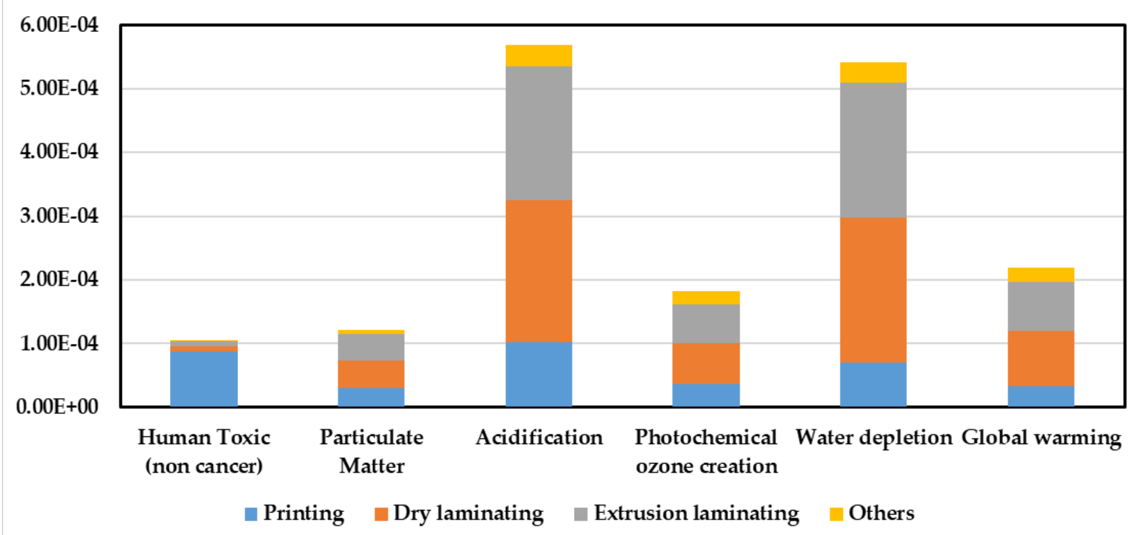

Fig. 7: Cumulative normalized impact of unit processes on six environmental consequences

Table 7: Results of feasibility survey

Impact category	Key-issue	Expected solution (alternative)	Feasibility study 1	2	3	4	5
Acidification Global warming Photochemical ozone creation Particulate matter	LNG use in laminating	Improve energy efficiency in laminating			○		
Water depletion	Reduce LDPE in laminating	Reduce quantity of LDPE film on packaging				○	
Human toxicity	Reduce ink in the printing process	Reduce number of colors and ink usage on packaging	○				

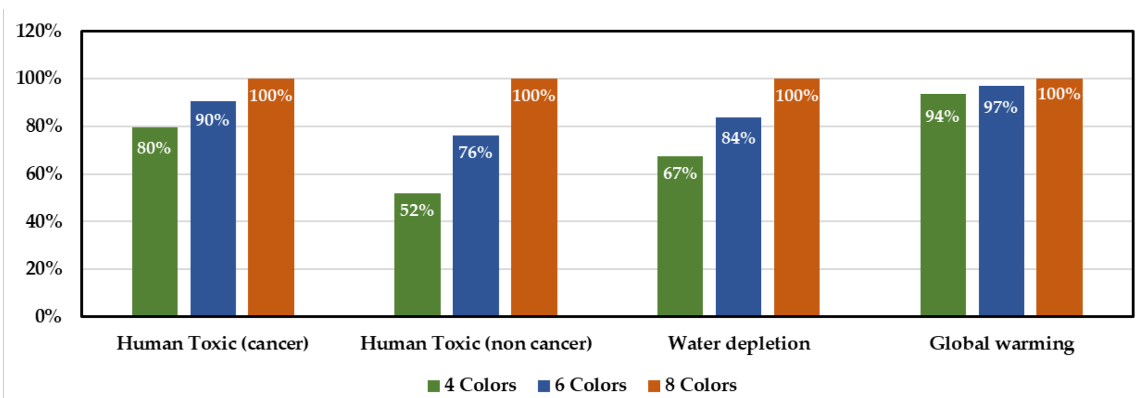

Fig. 8: Sensitivity analysis of environmental impact from reducing the number of colors

Table 8: Normalization results under two scenarios

Scenario	Normalized toxicity reduction (non-cancer)		Total area of packaging film (m^2)	Total toxicity reduction	
	Amount	Unit		Amount	Unit
8 colors → 6 colors	2.93E-05	PE/m^2	311,144,480	9.13E+03	PE
8 colors → 4 colors	5.44E-05	PE/m^2		1.69E+04	PE

As another indication of relative magnitudes, Figure 7 profiles cumulative normalized impacts of four unit processes on the same six environmental consequences. Printing contributes the most to human toxicity (non-cancer). Dry and extrusion laminating generate significant acidification, water depletion, and global warming. Contributions by other unit processes to particulate matter and photochemical ozone creation are similar.

c) Scenario analysis

This study identifies main issues for reducing the environmental impact of food packaging and proposes solutions. We selected solutions by benchmarking the best green packaging practices from the Korea Eco-Packaging Promotion Institute [20]. We then surveyed environmental experts and process engineers to rank their feasibility. More than 30 responded [21]. Their rankings appear in Table 7.

Respondents deemed our first solution to a long-term alternative because it required new equipment to improve energy efficiency. Also, reducing the use of LDPE film can erode the quality of food packaging, and the Gwangju factory was reluctant to apply it.

Respondents selected our third solution—curtailing the use of ink—as the best for reducing the environmental effects of food packaging. That solution can be applied soonest and would be palatable to managers because it exemplifies best practices at other companies.

To analyze the environmental benefit of fewer colors on the packaging, we selected four environmental consequences—human toxicity (cancer), human toxicity (non-cancer), water depletion, and global warming—that relate directly and indirectly to ink. We set scenarios for the number of colors from eight to four. The first (second) was to reduce the number from eight to six (from eight to four). The effect of eight colors on four impact categories was 100% as the reference value.

Human toxicity (non-cancer) is most sensitive to reducing the number of colors (Figure 8). The least sensitive is global warming. Reducing the number by half portends to reduce human toxicity (non-cancer) 48% and global warming 6%.

We also analyzed how fewer colors on food packages potentially reduce human toxicity. We set the reference value for this analysis at 1.05E-04 PE/m2, the normalized value of human toxicity effects (non-cancer) in Table 6. Potential reductions in normalized human toxicity from solutions 1 and 2 were 2.93E-05/m2 and 5.44E-05/m2, respectively. According to the Processed Food Market Status by the Korea Agro-Fisheries & Food Trade Corporate, yearly consumption of packed instant ramen was 76 pieces per capita in 2015 [22]. Accordingly, the number of instant ramens consumed in Korea in 2015 would have been 3.91 billion pieces. We calculated the surface area of all ramen packaging in South Korea as 311,144,480 m2 by multiplying all the ramen eaten there by the average surface area of one piece of ramen (7.56E-02 m2). We then divided by production yield (95.1%) in Table 2. The reduction in human toxicity (non-cancer) by applying both option 1 and 2 in 2015 would have been 9.13E+03 PE and 1.69E+04 PE, respectively. Table 8 indicates that 9,130 Korean and 16,900 Koreans could have avoided human toxicity (non-cancer) applying scenario 1 and 2, respectively.

III. Conclusion

The rapid increase in packaging waste generated by the rising consumption was recognized as a social problem. In particular, companies promote food products with colorful packaging printed with various inks to increase the selection rate for purchasing. In this situation, the importance of green packaging with the technologies of container lightening, recycling, reuse, and reduction of printing ink consumption was increasing. Among these technologies, reduced use of printing ink emerged as the most feasible technology using a Delphi method. We performed an LCA to evaluate the potential environmental impact on two options. Results indicate that reducing the number of colors of food packaging contributed significantly to decreasing human toxicity (non-cancer), but the effect on global warming was slight. Up to 16,900 persons would suffer less toxicity (non-cancer) if all ramen packaging in South Korea in 2015 featured fewer colors. To develop sustainable consumption and production, the benefits or green packaging technology should disseminate throughout South Korea.

Acknowledgments

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References Références Referencias

1. Shin, J.M.; Susan, E.M.S. *Chapter 11 Food Packaging, Food Processing: Principles and Applications (2nd edition)*, WILEY Blackwell, 2014, 249–273.
2. Korea Statistical Information Service. Available online: https://kosis.kr/index/index.do (accessed on 07 May 2019).
3. National Law Information Center. Available online: http://www.law.go.kr/LSW/eng/engMain.do (accessed on 25 May 2019).
4. Korea. *The first resource recycling basic plan*, Korea Government: Sejong-si, Korea, 2018.
5. MOE. *Press releases: Start the assessment of the circulation utilization of products such as PET*

bottles, Ministry of Environment: Sejong-si, Korea, 2018.

6. ATFIS. Major Statistics of Food Industry in 2017, Korea Agro-Fisheries & Food Trade Corporation: Naju-si, Korea, 2017.
7. ISO. *ISO 14040:2006: Environmental Management–Life cycle assessment–Principles and framework;* ISO: Geneva, Switzerland, 2006.
8. ISO. *ISO 14044:2006: Environmental Management–Life cycle assessment - Requirements and guidelines;* ISO: Geneva, Switzerland, 2006.
9. Lee, Y.S. *Flexible packaging technology*, 2013, https://blog.naver.com/synergypack/20186799732 (accessed on 25 May 2019).
10. Rozalia S. *Printing on Polymers: Fundamentals and Applications,* Elsevier, 2016, 199–215.
11. Durling, W.E. *Flexible Packaging Printing Processes Overview,* Consumer Packaging Solutions for Barrier Performance Course, 2009.
12. EC. *COMMISSION RECOMMENDATION on the use of common methods to measure and communicate the life cycle environmental performance of products and organizations,* 2013.
13. MOE. *National Waste Statistics*, Ministry of Environment: Sejong-si, Korea, 2017.
14. PE. *Eco-profiles*, https://www.plasticseurope.org /en/resources/eco-profiles (accessed on 25 May 2019).
15. Thinkstep. M*LCA Database*, https://www.gabi-software.com/international/databases/ (accessed on 25 May 2019).
16. Wolf, M.A.; Pant, R.; Chomkhamsri, K.; Sala S.; Pennington, D. *The international reference life cycle data system (ILCD) handbook,* Joint Research Centre, European Commission: Brussels, Belgium, 2012.
17. Ecoinvent: LCI Database & LCIA Results, www.ecoinvent.org/database/hot-to-use-ecoinvent-3-online/lci-datasets-and-lcia-results/lci-datasets-and-lcia-results.html (accessed on 25 May 2019).
18. Fantke, P. *USEtox 2.0 Documentation (Version 1.1),* Technical university of Denmark: Lyngby, Denmark, 2018, 21–23.
19. Benini, L.; Mancini, L.; Sala, S.; Manfredi, S.; Schau, E.M.; Pant, R. *Normalization method and data for Environmental Footprints,* Joint Research Centre, European Commission: Brussels, Belgium, 2014.
20. Korea Eco-Packaging Promotion Institute (KEPI) website. Available online: https://www.keppi.org/ (accessed on 25 May 2019).
21. Henrikke, B.; Tomas, R. *A comparison of three methods for impact analysis and evaluation,* Journal of cleaner production, Vol 2, 1994, 13–20.
22. Kim, J.S. *Processed Food Market Status,* The Korea Agro-Fisheries & Food Trade Corporate: Naju-si, Korea, 2015.