Section A-Research paper
ISSN 2063-5346

REPLACING EXISTING PACKAGING MATERIALS WITH MONO-MATERIAL POLYPROPYLENE BASED PACKAGING SUBSTITUTES

Ankit Boora[1], Suman Kumari[2], Bijender[3]

1. Assistant Professor, Department of Printing Technology, GJUS&T, Hisar, Haryana
2. Research Scholar, Department of Printing Technology, GJUS&T, Hisar, Haryana
3. Assistant Professor, Department of Printing Technology, GJUS&T, Hisar, Haryana

doi: 10.48047/ecb/2023.12.si6.80

ABSTRACT

Packaging with its single use component, is one of the most significant contributors to the waste worldwide. Rising consumer awareness about the environmental impact of plastic packaging and strict government regulations has put packaging on the foremost agenda of the Fact Moving Consumer Good (FMCG) companies. Thus, companies are looking for sustainable packaging options to minimize the environmental impacts. Conventional flexible packaging structures are made up of different layers which are difficult to separate and in turn difficult to sort and recycle with current recycling infrastructure across nations. In the current research work, redesign or rethink concept is used for creating a sustainable packaging structure by replacing the present multi-material structure with a mono-material Poly Propylene (PP) based multi-layer packaging material. With mono-material based structure all of the above issues are resolved and this helps to create a closed loop economy which is ultimate objective of sustainable development.

KEYWORDS:- Packaging Materials, Mono-material, Re-design, Sustainable Packaging

INTRODUCTION

Flexible packaging is a cost effective and lightweight solution as compared to other alternative options of packaging. But most of the packaging structure are not sustainable i.e. they don't form closed loop economy as recycling of multilayer structure is difficult. First of all, different polymer has different melting points and therefore they are not miscible and cannot be re-granulated. Secondly, for recycling the material needs to be identified in order to send it to correct waste stream. But the present infrastructure which is based on mechanical recycling and NIR sorters are not able to sort material on the basis of dominant material rather they identify material on the basis of either the outer layer or inner layer. Thus, there are high chances of material going to wrong waste stream and further there are chances of spoil of the quality of the recycled end product produced. To this the mono-material is the

ISSN 2063-5346

solution which can be easily identified, sorted and recycled and it creates a closed loop. However, the packaging structure do consist of other component such as metallisation or barrier material in it, but as per globally tolerance limits, upto 5% is considered as acceptable. Besides this there are many challenges when it comes to replacing a multi-material packaging structure with a mono-material among which the foremost is meeting the shelf –life of the product which depends on the barrier properties of packaging material i.e. WVTR and OTR, the required strength and last but not the least is the optimum seal-ability on high speed machines. By taking these requirements in mind we can switch to mono-material based structure and thus create a sustainable plastic packaging economy a reality.

RESEARCH OBJECTIVES

The objective of this research project is to explore the possibilities of replacing the conventional packaging material with the sustainable alternatives. In this research "Redesigning" concept is applied to the current multi-material multilayer (two layers) packaging material to provide an alternate sustainable mono-material PP based multilayer packaging material.

RESEARCH METHODOLOGY

1. Existing multi-material multilayer structure have been taken for consideration,
   - 12µPET/25µ White PE
2. Using Redesign Concept select best possible alternate option of mono- material PP i.e. Polypropylene based (both CPP i.e. Cast Polypropylene and BOPP i.e. Bi-axially oriented Polypropylene form are different oriented form of PP) multilayer packaging material is identified,
   - 18µHB HR BOPP/25µ White CPP

Structure	Existing Structure	Redesigned Structure
Redesign Concept	Multi-material Two layer structure 12µPET/25µ White PE	Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP

3. The analysis and testing of existing multi-material multilayer structure is done in terms of its properties which are important from the product point of view as well as from machinability perspective.
4. The analysis and testing of alternate mono-material PP based multilayer packaging material is done in terms of its properties which are important from the product point of view as well as from machinability perspective.
5. Comparison of the test results of both existing multi-material multilayer structure and mono-material PP based multilayer structure is done and comparison charts are prepared.

DATA COLLECTION AND ANALYSIS

Seal Strength

Table 1.1 Seal Strength Existing and Redesign Concept

Temperature:- 130°C		
Dwell time:- 01 sec		
Pressure:- 02 bar (200 KPa)		
Instrument used:- Llyod UTM		
Unit of Measurement:- Kgf/cm2 or N/m		
Sample	Multi-material Two layer structure 12µPET/25µ White PE	Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP
S1	3905	2520
S2	3885	2538
S3	3918	2551
S4	3954	2489
S5	3825	2408
S6	3756	2389
S7	3827	2409
S8	3889	2542
S9	3836	2428
S10	3918	2557

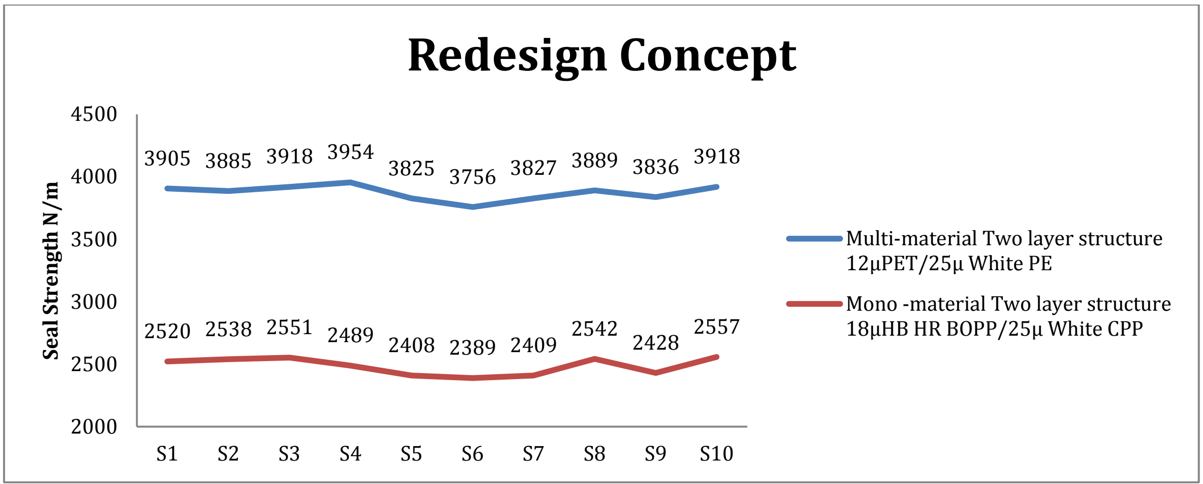

Figure 1.1 Comparison of Seal Strength for Existing and Redesign Concept

Tensile Strength

Table 1.2 Tensile Strength Existing and Redesign Concept

Instrument used:- Llyod UTM		
Unit of Measurement:- Kgf/cm2 or N/m		
No of Readings	Multi-material Two layer structure 12µPET/25µ White PE	Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP
S1	545	482
S2	567	521
S3	601	472
S4	559	491
S5	595	479
S6	580	480
S7	570	465
S8	565	485
S9	575	475
S10	586	510

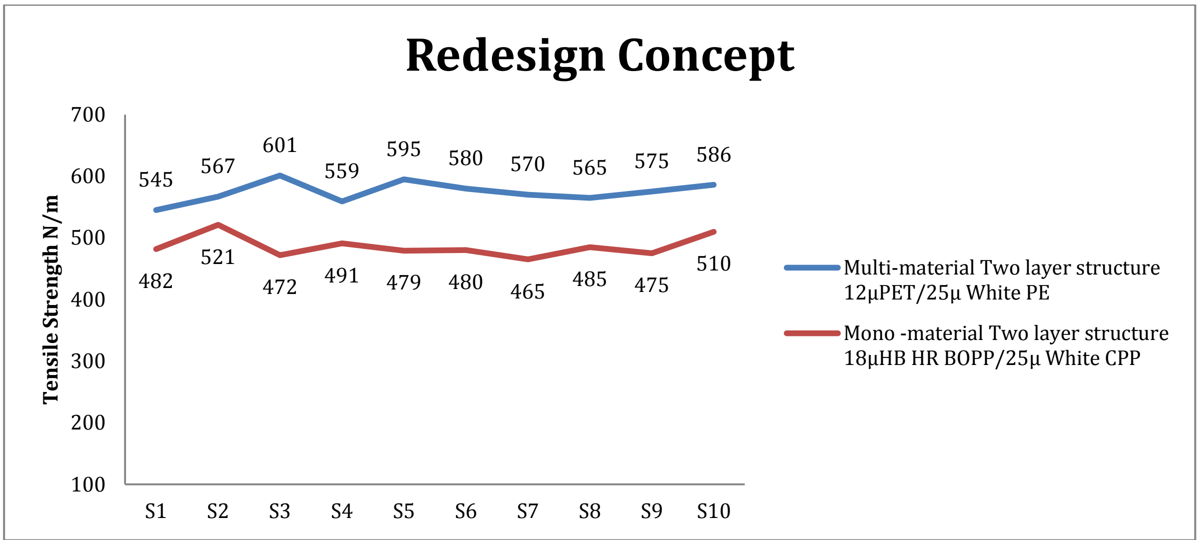

Figure 1.2 Comparison of Tensile Strength for Existing and Redesign Concept

Bond Strength

Table 1.3 Bond Strength Existing and Redesign Concept

Instrument used:- Llyod UTM		
Unit of Measurement:- gf		
No of Readings	Multi-material Two layer structure 12µPET/25µ White PE	Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP
S1	478	312

S2	512	330
S3	509	321
S4	486	365
S5	506	342
S6	492	326
S7	504	342
S8	498	340
S9	510	335
S10	502	355

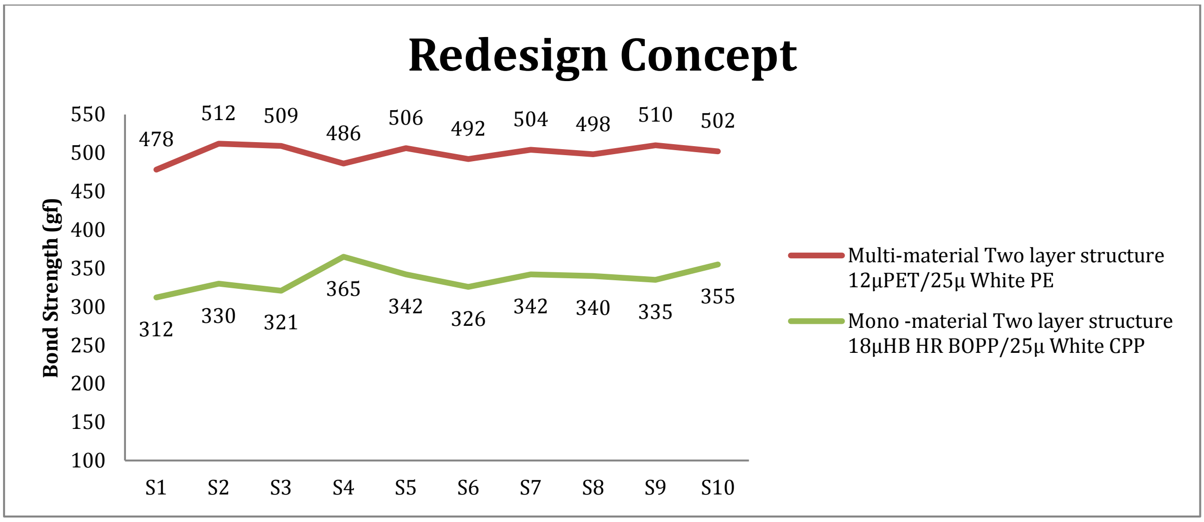

Figure 1.3 Comparison of Bond Strength for Existing and Redesign Concept

COF (Coefficient of Friction)

Instrument used:- UTM with COF Apparatus				
Unit of Measurement:- NA				
Sample	Multi-material Two layer structure 12µPET/25µ White PE		Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP	
	Static	Dynamic	Static	Dynamic
S1	0.27	0.24	0.33	0.31
S2	0.28	0.24	0.33	0.3
S3	0.27	0.23	0.32	0.31
S4	0.25	0.21	0.31	0.31
S5	0.26	0.19	0.32	0.31
S6	0.27	0.21	0.32	0.3
S7	0.25	0.20	0.33	0.29
S8	0.27	0.19	0.32	0.3

S9	0.26	0.22	0.33	0.31
S10	0.25	0.24	0.31	0.29

Table 1.4 COF Existing and Redesign Concept

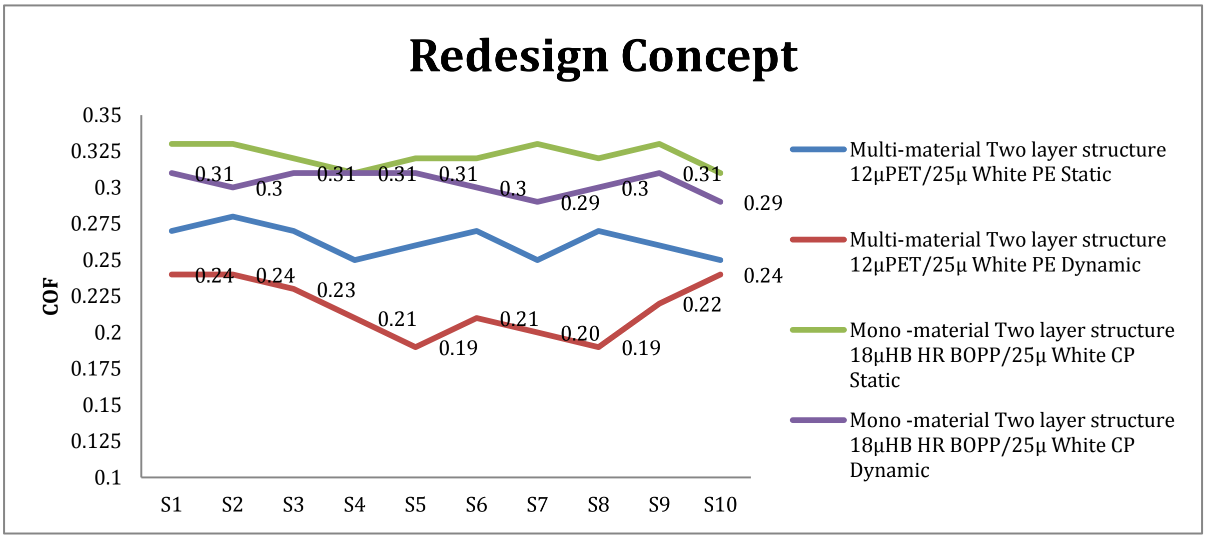

Figure 1.4 Comparison of COF for Existing and Redesign Concept

Opacity

Table 1.5 Opacity Redesign Concept

Instrument used:- X-Rite		
Unit of Measurement:- %		
Redesign Concept		
Sample	Multi-material Two layer structure 12µPET/25µ White PE	Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP
S1	85	84

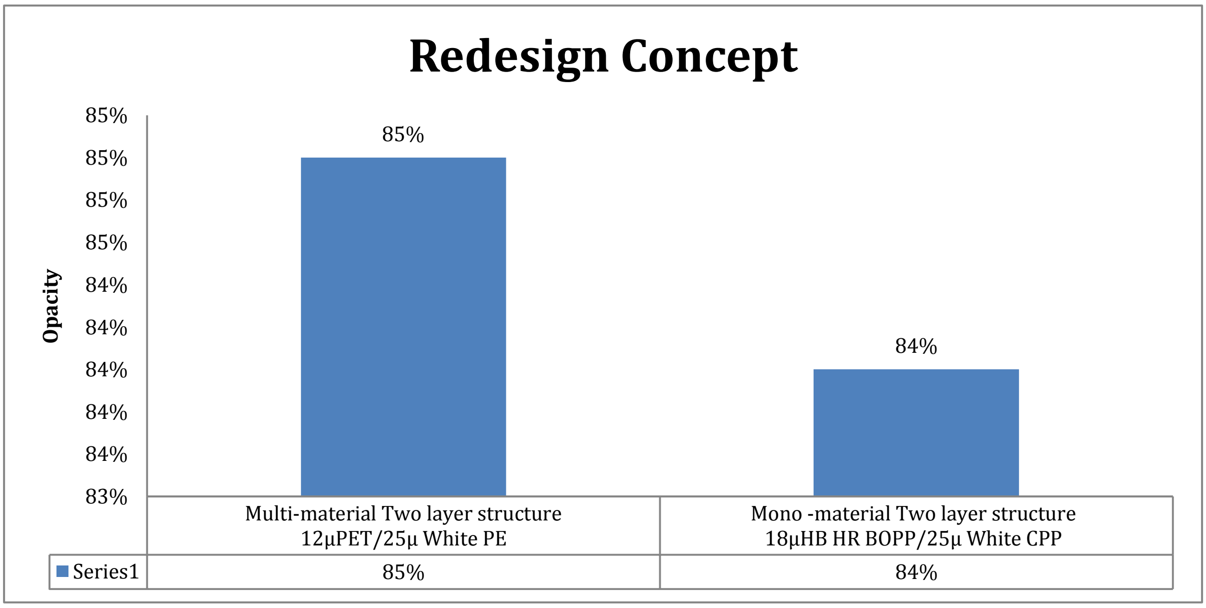

Figure 1.5 Comparison of Opacity for Existing and Redesign Concept

Section A-Research paper
ISSN 2063-5346

Seal Initiation Temp – SIT

Table 1.6 Seal Initiation Temp Existing and Redesign Concept

Instrument used:- Llyod UTM				
Redesign Concept 1				
Structure	Multi-material Two layer structure 12µPET/25µ White PE		Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP	
Pressure	02 bar		02 bar	
Time	01 sec		01 sec	
Orientation	**TD**	**MD**	**TD**	**MD**
Temperature	95 Deg C	96 Deg C	95 Deg C	96 Deg C

SIT is the temperature where a min of 125g/25mm seal force is achieved. In the new redesigned concept the SIT is improved to 95Deg C through use of additive in CPP which is otherwise approx. 118-120 Deg C for CPP.

Test condition: Heat sealer used: RDM heat sealer

Machine for testing – UTM (Universal Testing Machine)

Hot Tack

Table 1.7 Hot Tack Existing and Redesign Concept

Parameters		
SET 1 (seal time) :- 01 sec		
Cool Time :- 0.1 sec		
SET 1 (pull time) :- IMMEDIATE		
Temperature:- 130 °C		
Pressure:- 02 bar		
Instrument used - RDM HT - 2PC		
Sample	Multi-material Two layer structure 12µPET/25µ White PE	Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP
S1	1351	1421
S2	1298	1501
S3	1438	1487
S4	1521	1424
S5	1385	1532

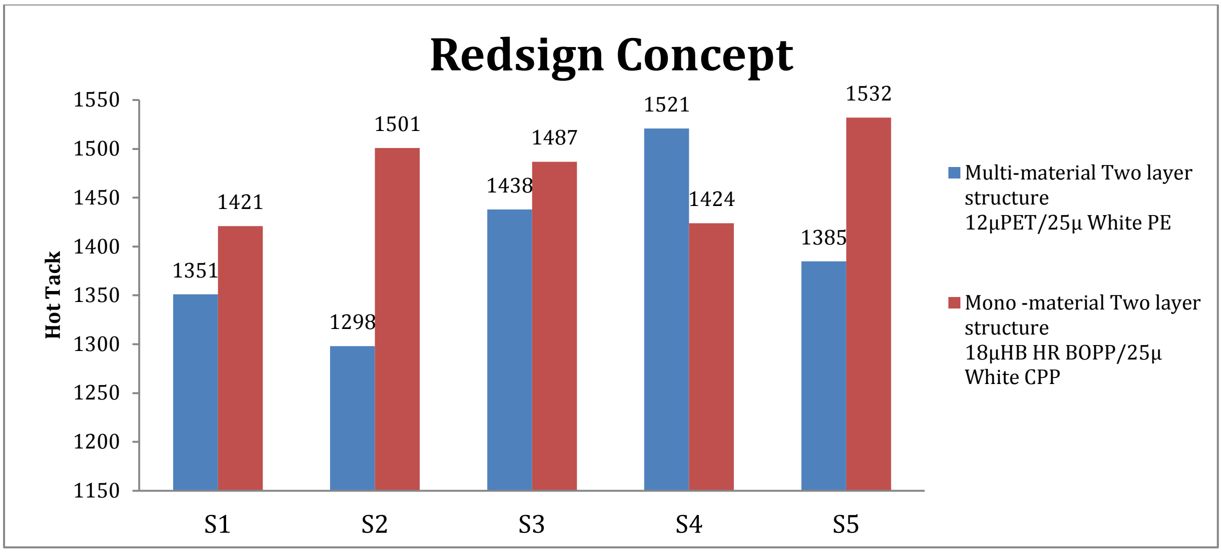

Figure 1.6 Comparison of Hot Tack for Existing and Redesign Concept

Water Vapour Transmission Rate (WVTR)

Table 1.8 WVTR Existing and Redesign Concept

Instrument used:-MOCON PERMATRAN-W® Model 3/34 G		
Unit of Measurement:- g/m^2/24hrs		
Sample	Multi-material Two layer structure 12µPET/25µ White PE	Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP
S1	13.84	6.89
S2	14.12	6.82

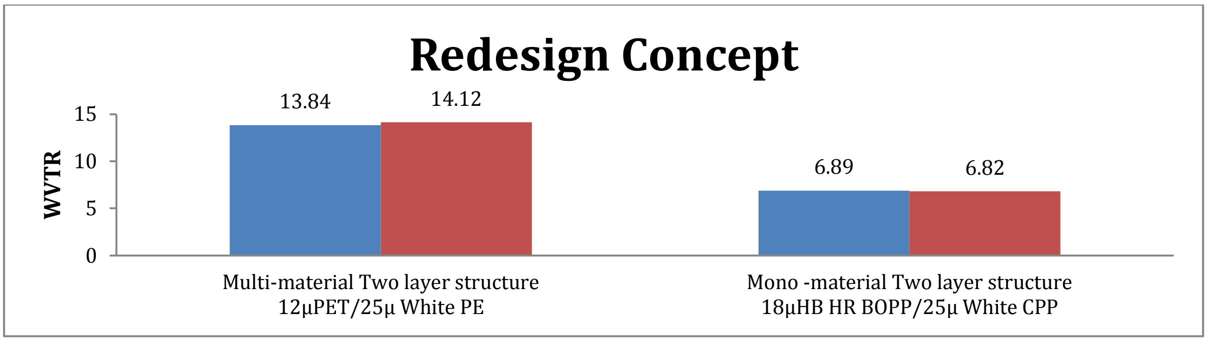

Figure 1.7 Comparison of WVTR for Existing and Redesign Concept

Oxygen Transmission Rate (OTR)

Table 1.9 OTR Existing and Redesign Concept

Instrument used:- MOCON OX-TRON 2/21		
Unit of Measurement:- cc/m^2/24hrs		
Sample	Multi-material Two layer structure 12µPET/25µ White PE	Mono -material Two layer structure 18µHB HR BOPP/25µ White CPP

S1	109.8	84.6
S2	112.6	90.5

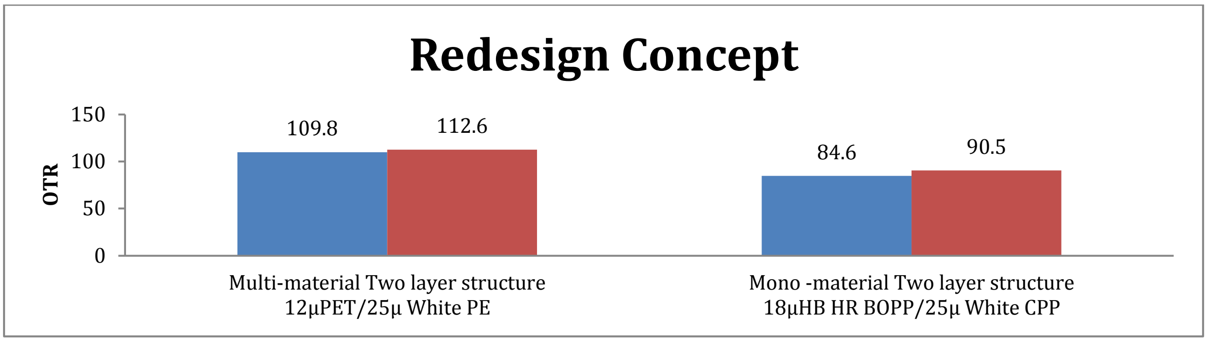

Figure 1.8 Comparison of OTR for Existing and Redesign Concept

RESULT AND DISCUSSION

On the basis of detailed study of all the parameters of existing and redesigned structure it is resulted that presently used multi-material multi-layer packaging designs can be redesigned into mono-material PP i.e. Polypropylene based multilayer structure.

Redesigning is performed for the existing multi-material two layer structure 12μPET/25μWhite PE into mono -material two layer structure 18μHB HR BOPP/25μ White CPP. The old structure is based on PET (Polyethylene Terephthalate) which belongs to polyester family and PE which belongs to Polyolefin family which makes this structure non-sustainable from recycling point of view (difficulty in detecting by NIR, sorting and recycling). Earlier we have discussed in this report that as per Ceflex Report June 2020 we can design a sustainable packaging material either by using mono-material single layer packaging option or mono-material multilayer structure (based on certain limits on metallisation or EVOH) (Bauer et al. 2021). The new structure is based on BOPP i.e. Bi-axially Oriented Polypropylene and CPP i.e. Cast Polypropylene which in turn are based on mono-material PP (Polypropylene) although with a different orientation.

When it comes to comparing the individual material in two structure, PET is an ideal choice for printable surface as it is polar in nature and hence surface treatment produce good results; high strength; good gas (oxygen, carbon dioxide) & moisture barrier properties; and high heat resistance (suitable for high speed machine) whereas BOPP has good moisture barrier but its gas barrier is not good, low temperature resistance and low surface energy (corona treatment is requirement as it is non polar in nature). Thus to improve the gas barrier of BOPP a coating of EVOH is used in the redesigned mono-material structure and it is corona treated for reverse printing.

The other material is PE (Polyethylene) which is a versatile sealant and provides best seal integrity. Besides this it also belong to Polyolefin family (or PE family), so in the proposed new structure we could have used BOPP/PE but as we know the polymer miscibility is an important parameter. If materials are miscible they can be directly re-granulated.

ISSN 2063-5346

The polymer PP, PE, PET, PA, and PS are generally immiscible at molecular level. Thus a sustainable alternate, CPP is used which is not that good sealant as PE but has been modified to achieve good sealing properties. While considering economically it is little more costly from the present structure but considering the cost to environment, people's environmental conscious preference and determination of companies to move towards sustainability it is the right option in this direction.

When the properties of both the structures are compared, it can be analyzed that machine requirement for Seal Strength (Table 1.1) and COF (Table (1.4) are comparable and product requirement for WVTR (Table 1.8) and OTR (Table 1.9) are also good for new proposed structure.

CONCLUSION

The new mono-material PP based multilayer structure is completely tested for all the relevant parameters and found to provide satisfactory results from the perspective of products barrier requirement as well as from machinability point of view. Thus this redesigned mono-material PP based multilayer laminate is a good sustainable option to the presently used multi-material multilayer packaging material.

REFERENCES

1. Van Velzen, Ulphard Thoden, Lisanne de Weert, and Karin Molenveld. *Flexible laminates within the circular economy*. No. 2037. Wageningen Food & Biobased Research, 2020.
2. Schmidt, Jannick, Laura Grau, Maximilian Auer, Roman Maletz, and Jörg Woidasky. "Multilayer Packaging in a Circular Economy." *Polymers* 14, no. 9 (2022): 1825
3. Lewis, Helen, Leanne Fitzpatrick, Karli Verghese, Kees Sonneveld, Robert Jordon, and Sustainable Packaging Alliance. "Sustainable packaging redefined." *Melbourne, Australia: Sustainable Packaging Alliance* (2007).
4. Sonneveld, Kees, Karli James, Leanne Fitzpatrick, and Helen Lewis. 2005
5. Parra, Susan. Guidelines for Material Selection for Sustainable Packaging Solutions. Rochester Institute of Technology, 2008.
6. Ceflex Dace, Phase 1 Guidelines_Technical report_SPREAD VIEW_low res June 2020
7. Svanes, Erik, Mie Vold, Hanne Møller, Marit Kvalvåg Pettersen, Hanne Larsen, and Ole Jørgen Hanssen. (2010)
8. Guillard, Valérie, Sébastien Gaucel, Claudio Fornaciari, Hélène Angellier-Coussy, Patrice Buche, and Nathalie Gontard. (2018)
9. Huang, Chien-Chung, and Hwong-Wen Ma (2004).