E3S Web of Conferences **495**, 03003 (2024) https://doi.org/10.1051/e3sconf/202449503003
ICYES 2023

Consumer-driven evaluation of Ecoplas as a sustainable flexible packaging in Jakarta

Azat Sudrajat[1], *Susanti* Withaningsih[1,2,3], and *Sunardi*[1,2,3]

[1]Master Program on Sustainability Science, Graduate School, University of Padjadjaran, Indonesia
[2]Environment Science Program, Graduate School, University of Padjadjaran, Indonesia
[3]Center for Environment and Sustainability Science, University of Padjadjaran, Indonesia

Abstract. 400 million tons of plastic waste pollute the environment every year, and then 8 million tons of plastic waste have ended up in the ocean. Flexible plastic waste accounts for 76% of plastic waste entering the environment in Indonesia. Ecoplas have been developed in Jakarta, as starch-based biodegradable packaging. This study aims to 1) determine the ranking of Ecoplas compared to PP, r-PP, and Oxo-biodegradable; 2) Identify criteria that affect the path of Ecoplas packaging into sustainable packaging. Data collection was conducted through a questionnaire involving 96 consumers of flexible packaging in Jakarta, taken by convenience sampling. In this study, Ecoplas packaging was evaluated using PROMETHEE II to generate rankings, and Rainbow-PROMETHEE to review criteria affecting packaging sustainability. The results show that PP packaging (0.1168) remains the most preferred option for flexible packaging, followed by Oxo-biodegradable (0,0020), Ecoplas (-0,0113), and r-PP (-0,1076). Ecoplas have good criteria on willingness to purchase (Ec), consumers' environmental preferences (En), property preference (T1), packaging safety preference (T3), and consumer knowledge of post-consumer (S2). Aspects of criteria that need to be improved by Ecoplas i.e. awareness of alternative packaging usage (S1) and accessibility (S3 & S4), and packaging durability preference (S2). Ecoplas is promising to be an alternative to flexible packaging, as shown by the good evaluation and willingness of consumers to purchase it as eco-friendly packaging. However, Ecoplas packaging needs to improve the level of packaging properties and accessibility level for consumers to find it easily.

1 Introduction

Flexible plastic garbage is becoming more prevalent and outnumbers other types of plastic waste. Flexible plastic trash accounts for 76% of plastic garbage that escapes into the environment in Indonesia. The monolayer type of flexible plastic packaging trash dominates in Jakarta, accounting for 48%, followed by the type of plastic & metal combination, accounting for 33%, and the type of plastic & plastic layer accounting for 19%. % [1], [2].

Living things, including humans, can be harmed by plastic garbage. Plastic pollution has the potential to disrupt health by interfering with reproductive, hormonal, metabolic, and neurological functions. Furthermore, plastic trash can enter the body through food, drinks, or the air we breathe every day, especially if it is in the form of microplastics. Once in the body, these plastic particles can impact the health of living humans by impairing the performance of organ systems [3], [4].

Thus, to solve this problem, bioplastics have been developed to help plastic easily decompose in nature. Numerous biodegradable plastics have been developed, including oxo-biodegradable, fossil-based biodegradable plastic and biobased biodegradable or compostable type bioplastics. The goal of this plastic technology is to harness the benefits of plastic while minimizing environmental impact [5]–[7].

The management conditions and post-use management systems are among the challenges faced when implementing biodegradable renewable products, as described in multiple studies. Laws have not yet been established to regulate how bioplastics are collected. It is therefore a concern that the disposal of this type of material only leads to its disposal along with hazardous waste, conventional plastics or municipal waste [8]–[10].

On other side, there are several studies that prove the effectiveness of biodegradable plastics. Some research explained that the type of oxo-biodegradable undergoes changes in chemical structure as a result of oxidation in the air, causing damage from molecules into small fragments which are then bio assimilated. There is also a study that shows the addition of oxo-biodegradable to a mixture of PP and PP / PLA can accelerate decomposition. Similarly, in the research the toxicity by microalgae which proved oxo-biodegradable has a lower negative impact on microalgae growth so that it has the potential not to have a negative impact on the environment [11]–[14].

The industry still requires the use of biodegradable plastic packaging. Indeed, biodegradable packaging initiatives are encouraged and designed to reduce conventional plastic waste but can also meet manufacturers' needs to maintain product quality. Therefore, the biodegradability of bioplastic packaging should be a solution to reduce plastic waste while paying attention to the functionality of packaging from an industrial point of view.

Bioplastics have been developed in Indonesia and could potentially replace conventional plastics. The types of bioplastics developed are very diverse, from materials of bio-based to fossil-based materials that are easily biodegradable. Several research described the potential of bioplastics both in terms of raw materials and biodegradability. The quality improvement of bioplastics continues to improve, as bioplastic packaging is considered the future generation of smart packaging [15], [16].

Ecoplas is composed of a mixture of polyolefin and tapioca which is designed in such a way that it can be used properly as packaging. Currently, Ecoplas has grown a lot to be used in various applications such as shopping bags, monolayer flexible packaging, landfill covers, eco-wraps and others. This type of bioplastic is believed to be decomposed within 12-24 months [17], [18].

That fact is in line with the biodegradability rate of Ecoplas which reached 32.4-33.2% within 90 days. These results are certainly in line with ASTM D5988 standards which require decomposition rates to reach 60-90% within 60-180 days in a composting environment. Biodegradability of materials has been defined as the ability to undergo decomposition into carbon dioxide, methane, water, inorganic compounds or biomass primarily by enzymatic action [19], [20].

An analytical technique through the Preference Ranking Organization Methods for Enrichment Evaluation (PROMETHEE) approach is one method that can complement sustainability evaluation, to measure the sustainability performance of a product, service or policy. As part of Multi-Criteria Analysis (MCA), PROMETHEE has been widely used in sustainability analysis both in sustainable regional planning, sustainable resource utilization, and energy planning to sustainable environmental management. The PROMETHEE approach is used because it is one of the significant methods for evaluating alternatives through criteria in multi-criteria decision-making problems. This is characterized by the many types of preference functions used to determine the differences between alternatives in their assessment. [21]–[23].

PROMETHEE is ideally to the product and material level. For example, the fuzzy PROMETHEE method is used based on trapezoidal fuzzy interval numbers as an application in the selection of sustainable automotive instrument panel materials. PROMETHEE to assess the geometry of complex shapes in various engineering materials that are difficult to cut in the Powder Mixed Electrical Discharge Machining (PMEDM) process that it is more sustainable [24], [25].

PROMETHEE applied to propose the preference of suppliers of "green" materials under the criterion preference function. Comparable results are presented to examine the effect of different preference functions on the final preference. Seven economic and environmental criteria, four suppliers and five decision makers were the main structures in the issue of selecting environmentally friendly suppliers in the study [26].

Therefore, a sustainability evaluation will be conducted using the PROMETHEE method in this study to evaluate the usage of Ecoplas. This approach aims to 1) determine the ranking level of Ecoplas compared to other packaging; 2) determine the factors that influence Ecoplas to be a sustainable packaging.

2 Material and methods

2.1 List & weight of criteria

The sustainability indicators used to assess Ecoplas packaging as an alternative to flexible packaging in this study are divided into property, social, economic and environmental dimensions. There are 9 parameters that focus on consumer assessment and are used as a reference for the evaluation process. The parameters have been evaluated and given a weight score by 8 experts representing interested parties, namely industry owners of bioplastic technology (2 technology brands), bioplastic researchers (2 institutions), government (2 institutions) and Non-Government Organizations that focus on bioplastic issues in Jakarta (2 institutions).

The weighting was carried out starting with the presentation of the criteria to the experts, then the experts evaluated and recommended the criteria. After that, the experts gave a value to each criterion through numbers 1-9 (1: very unimportant, 9: very important). Next, the results of the weighting carried out by the experts were normalized. The calculation refers to the normalization formula (Wj) [27], [28]:

$$Wj = \frac{wj}{\sum wj} \quad (1)$$

Description:
wj = Criteria assessment weight
∑wj = Sum of criteria weights

Table 1 List of criterias

No	Parameter
T.1	Consumer preference for packaging property level
T.2	Consumer preference for packaging durability in maintaining product quality
T.3	Consumer preferences for packaging safety such as being safe from toxins, including in contact with food etc.
En	Level of consumer preference to buy packaging based on the environmental benefits obtained

S.1	Level of knowledge of post-use packaging processing by consumers
S.2	Level of consumer awareness to use alternative packaging types
S.3	The level of consumer convenience in sourcing packaging
S.4	The level of frequency of consumption of packaging by consumers
Ec	The level of consumer preference to purchase packaging based on price

Data were obtained through online and offline questionnaires. Data was obtained from consumers of flexible packaging in Jakarta using convenience sampling technique (96 people). The scope of the assessment given by respondents is the use of Ecoplas, Oxo-biodegradable, recycle-PP (r-PP) and PP packaging as flexible packaging that has been circulating. The number of respondents used was calculated based on the formula of Lemeshow [29]:

$$n = \frac{z^2 p(1-p)}{d^2} \quad (2)$$

Description
n = Number of samples
z = standard value (1.96)
p = maximum estimated standard value (0,5)
d = alpha value that indicates the value of confidence (10%)

Then the minimum sample size used was 96 consumer respondents. Consumers were selected as respondents with the criteria 1) aged ≥17 years, 2) local residents, domiciled or working in Jakarta, and 3) familiar with Ecoplas packaging. Researchers used this approach because the population of respondents who fit the criteria is not known certainty [29].

2.2 Research time & place

The research was conducted from May-September 2023 in Jakarta and its surroundings by adjusting the location of respondents both on-site and online.

2.3 Description of alternatives

Biodegradable plastic is considered to be one of the solutions for reducing plastic waste. Microbes are thought to be able to eat biodegradable plastic particles so that the material is able to decompose faster in nature without producing microplastics compared to conventional plastics. This method makes biodegradable plastic one of the solutions that help minimize the environmental impact and reduce the accumulation of plastic waste effectively [30]. This study evaluates the sustainability of using Ecoplas as one of the biobased biodegradable packaging circulating in Jakarta by comparing it to alternative oxo-biodegradable packaging and packaging made from recycled polyethylene (rPP). In addition, conventional plastic packaging from polyethylene (PP) was also used as a control comparison.

2.3.1. Ecoplas

Ecoplas is made from a blend of polyolefin and tapioca that is designed to be used well as product packaging. Currently, Ecoplas has been widely developed to be used for various applications such as shopping bags, monolayer flexible packaging, landfill covers, ecowraps and others. This type of bioplastic is believed to be biodegradable within 12-24 months [17], [18].

The claim is in line with the Ecoplas biodegradability rate which reached 32.4-33.2% within 90 days. This result is certainly in line with ASTM D5988 standard which requires a decomposition rate of 60-90% within 60-180 days in a composting environment. Biodegradability of materials has been defined as the ability to undergo decomposition into carbon dioxide, methane, water, inorganic compounds or biomass mainly by enzymatic action [19], [20].

2.3.2. Oxo-biodegradable

Biodegradable plastics can be produced from oil or plant-based materials. Among the biodegradable plastics produced from oil, the majority of which are on the market are additives, one of which is known as oxo-biodegradable. Oxo-biodegradable is an additive technology that will make the plastic biodegradable. Oxo-biodegradable is defined by CEN as a degradation process resulting from oxidative and cell-mediated phenomena, either simultaneously or successively. This means that the plastic undergoes degradation by oxidation until its molecular weight is low enough to be eaten by bacteria and fungi, which then recycle it back into nature by cell-mediated phenomena [31], [32].

One of the studies conducted in the Arabian Gulf successfully observed the degradation process of PE, PET, and oxo-biodegradable PE in the marine environment at different depths of 2 and 6 meters. Scanning Electron Microscope (SEM), a type of electron microscope that produces images of samples by scanning the surface with an electron beam, showed remarkable crack formation in oxo-biodegradable PEs displaying physical degradation. As for the chemical degradation, carbonyl bonds, and hydroxyl groups were successfully detected on the oxo-biodegradable based plastic by Fourier Transform Infrared (FTIR). While in the biodegradation stage, Bacteriosetes, Proteobacteria, and Planctomycetes were found on all types of oxo-biodegradable plastics. Oxo-biodegradable plastics show many signs of degradation over time due to a combination of abiotic and biotic processes [33].

https://doi.org/10.1051/e3sconf/202449503003

There are several Oxo-biodegradable packaging available in Jakarta. Environmental impact testing on post-use of this type of packaging has been conducted. One of them is through testing the impact of microplastics on microalgae exposed by oxo-biodegradable which has the potential to have a lower negative impact on microalgae growth so that it has the potential to have no adverse impact on the environment compared to conventional HDPE plastic types [13], [14].

2.3.3. Recycled Polypropylene (rPP)

The use of recycled materials in packaging can improve environmental benefits. Among these benefits are in the form of resource efficiency and CO2 emission savings. Resource and carbon savings are determined by the amount of recycled content included, as well as the packaging and recycling methods. Additionally, the environmental benefit of incorporating recycled materials into plastic packaging is that it reduces the need for primary plastic raw materials and gives the materials new uses. Recycled plastic materials commonly used as packaging are PET and PP [34].

PP is potentially capable of being recycled four times in a "close loop" system before its thermal degradation adversely affecting its polymer bonds occurs. It was found that recycling PP resulted in a 15% increase in tensile strength and a decrease in its molecular weight, which contributed to the decrease in elongation at break and breaking strength of the new product. Recycled PP also has higher crystallization, higher crystallinity, and higher equilibrium melting temperature than virgin PP [35]–[37].

Recycled PP (rPP) can potentially be used 100% or often mixed with virgin plastic in a ratio of about 1:3 for the production of new plastic products. In addition, the resulting product is used as a polymer matrix in various additive composites. It is known that many different products can be obtained from recycled PP, such as: fibres, containers, boxes, garden borders, pots, pipes, polar waxes, lubricants, alternative concrete, lead-acid battery protectors, car parts, packaging and more [38], [39].

2.3.4. Polypropylene (PP)

Polypropylene (PP) is the best type of plastic for food and beverage packaging because it prevents chemical reactions and is resistant to relatively high temperatures. Polypropylene (PP) is one of the most promising thermoplastic polymer materials today. It is widely used in vehicles, home appliances, related services and other industries. As a versatile, adaptable material, the total use of polypropylene film occupies an important position and accounts for 30% of plastic films. Based on the processing method of polypropylene film, PP can be separated into IPP (blown film), CPP (cast film), and BOPP (biaxial polypropylene). Basically, PP is used as the outer or inner fabric layer of packaging. The outer layer (printed layer) is mostly formed by BOPP. Heat-sealable CPP is mainly used as the inner layer of bags [40], [41].

Polypropylene is a downstream petrochemical derived from the olefin monomer propylene. The polymer is made through a process of combining monomers called addition polymerization. During this process, heat, high-energy radiation, and an initiator or

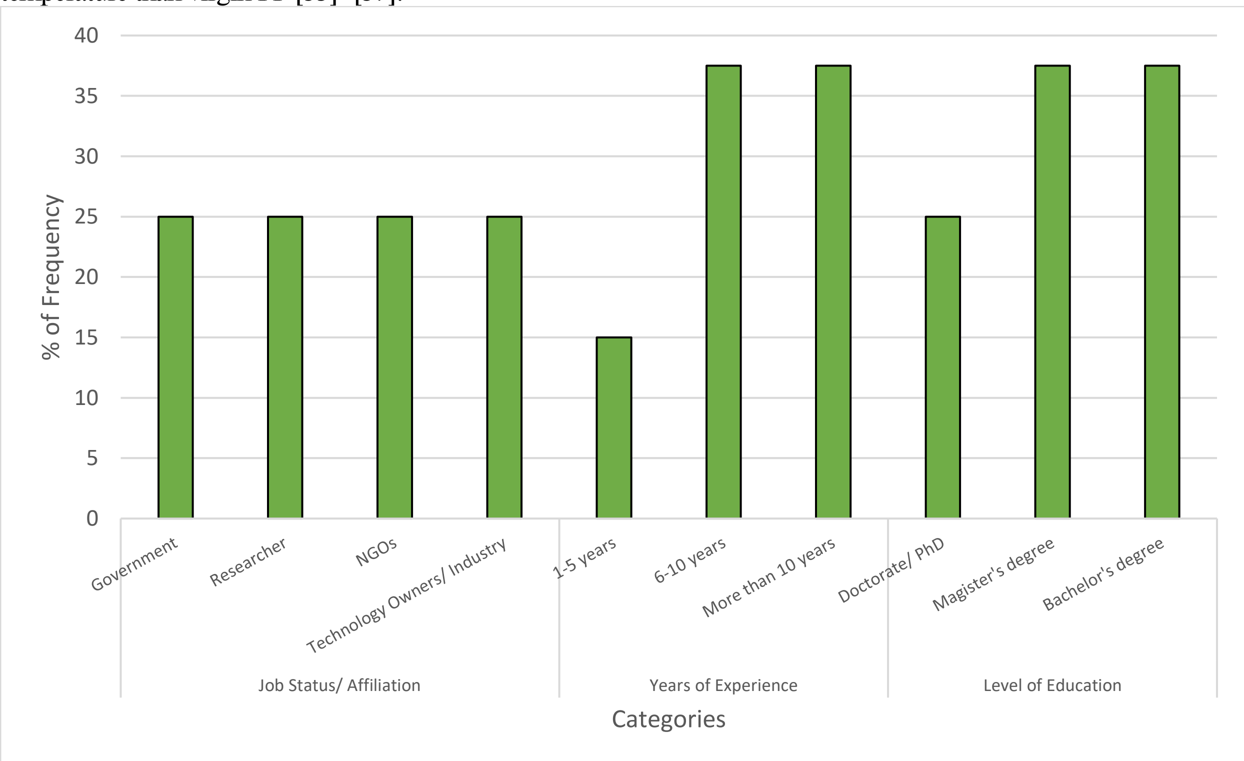


Fig. 1. Overview of the Experts

catalyst are added to combine the monomers. Therefore, propylene molecules are polymerized into very long polymer molecules or chains. The competitive price of polypropylene plastic and its versatile nature make this packaging the choice for a wide range of food products in all popular food packaging formats such as pots, containers, jars, bottles, pouches and packaging films [42].

2.4 PROMETHEE Analysis

The data obtained was then analyzed through PROMETHEE. As one of the multicriteria approaches, this research refers to Laapo et al., (2021); Sukwika et al., (2016); Sukwika & Noviana, (2020) with the aim of assessing the sustainability performance of Ecoplas use. This stage of the approach was also based on Abdullah et al., (2019); Das & Chakraborty, (2021); Fauzi, (2022); Pitcher et al., (2013); Pitcher & Preikshot, (2001), where there are several steps:

1. Indicator determination
   Each aspect of the sustainability of using sustainable packaging products is identified including environmental, social, technological, regulatory and economic dimensions;
2. Criteria weighting
   Each criterion was consulted with experts. Experts evaluate and provide assessment scores as weights. Experts rate the attributes of each dimension with a range between 1-9;
3. Alternative object data collection
   Data was obtained following the indicator criteria for the performance of alternative objects. The alternatives assessed are monolayer packaging made from Ecoplas, as well as 3 comparison packaging, namely conventional plastic packaging (PP), recycled PP packaging (r-PP), and Oxo-biodegradable packaging;
4. Compile a comparison matrix
   The data that has been obtained is compiled into a comparison matrix table after being calculated through the average respondent's assessment of each alternative and criterion. The data is then entered into the PROMETHEE academic version 1.4.0.0 software;
5. Determine the preference function
   The preference function using V-shape type [48];
6. Outranking calculation
   Outranking determination using PROMEHTEE II approach;
7. Reviewing influence parameters
   Determination of indicators that influence the sustainability of Ecoplas packaging through Rainbow-PROMETHEE.

3 Result

3.1 Weight of criteria

This research involved eight representatives of interested parties in the implementation of the use of biodegradable packaging bioplastics as one of the solutions to reduce plastic waste. The eight representatives consisted of government, industry or technology owners, NGOs and researchers who have expertise in bioplastics. A summary of the assessors who gave these weights is reviewed in table 2.

Table 2 Weight of Criterias

No. Of Criteria	Weight
EC	0,121479
T3	0,119718
T2	0,116197
S3	0,112676
EN	0,107394
S4	0,107394
S1	0,105634
S2	0,105634
T1	0,103873

Experts have evaluated and rated 9 criteria. The 9 criteria are approved by the experts to be used to quickly and easily assess the sustainability position of alternative packaging. The weighting results that have been carried out show the priority of the criteria determined to evaluate the advantages and disadvantages of alternative packaging. In addition, through the results of this weighting can be used as a reference in choosing the right packaging to use in the future.

As shown in table 3, the criterion with the highest weight value is owned by the criterion The level of public preference to buy products with related packaging based on price (Ec) with a weight value of 0.121. Meanwhile, the criterion that has the lowest weight value is the criterion of public preference for the level of packaging properties (T.1), which is 0.103.

3.2 Overview of Respondents

Respondents from consumers are intended to obtain assessment data to provide an overview of consumer assessment of each criterion. The data obtained is for all packaging alternatives, namely Ecoplas, Oxo-biodegradable, r-PP, and conventional PP which are applied as flexible monolayer packaging. Based on table 4, it is known that the majority of respondents based on education are undergraduate / equivalent (50 people), with unmarried marital status (55 people), with a gender balance of men (52 people) and women (44 people), the majority aged 24-29 years (47 people), the majority of Jakarta residents (73 people), and the majority work as private employees (44 people).

Table 3 Overview of Respondents

	Category	Total
Education	High school, vocational school or equivalent	38
	Bachelor's degree or equivalent	50
	SD	1
	Master/Doctoral	3
	D1, D2, D3 or equivalent	4
Marital status	Married	37
	Unmarried	55
	Divorced	4
Gender	Male	52
	Female	44
Age	18-23 years old	16
	24-29 years	47
	30-35 years	16
	36-41 years	15
	42-47 years	1
	48-53 years	0
	54-60 years	1
Nature of residence	Only live in DKI Jakarta	8
	Only work in DKI Jakarta	15
	Resident of DKI Jakarta	73
Profession	NGO activist	2
	Teacher	1
	Housewife	13
	Private employee	44
	Trader	10
	BUMN or BUMD employee	2
	Civil servants / TNI / Polri	10
	Student	12
	Unemployed	2

3.3 Preference ranking

Identification of the ranking preferences of the effectiveness of using Ecoplas as an alternative solution for flexible packaging using the PROMETHEE approach is operationalized based on the data from the comparison matrix results at Table 5. Then, the comparison data is processed into PROMETHEE along with the criteria weights that have been obtained through expert opinions on Table 3. The output produced by PROMETHEE is the ranking order of alternatives which is visualized in Fig. 2. Preference ranking of alternative packaging.

PROMETHEE II presents a complete ranking of alternatives. The results show that PP packaging (0.1168) is the most preferred as flexible packaging, followed by Oxobiodegradable (0.0020), Ecoplas (-0.0113) and r-PP (-0.1076). Recycle PP has the highest negative Phi score (0.4573) followed by Ecoplas (0.3154) (Fig. 2. Preference ranking of alternative packaging).

Table 4 Decision data matrix results from consumers

	Mean of average consumer rating (%)			
Criteria	PP	Ecoplas	Oxo-biodegradable	rPP
S1	25,02	25,11	23,58	26,28
S2	28,23	22,85	23,32	25,58
S3	30,49	22,04	22,11	25,34
S4	32,11	22,14	21,63	24,1
Ec	24,65	25,57	26,03	23,73
En	23,47	26,20	25,81	24,51
T1	22,15	26,46	26,84	24,53
T2	25,84	24,38	25,26	24,5
T3	24,32	25,81	26,07	23,8

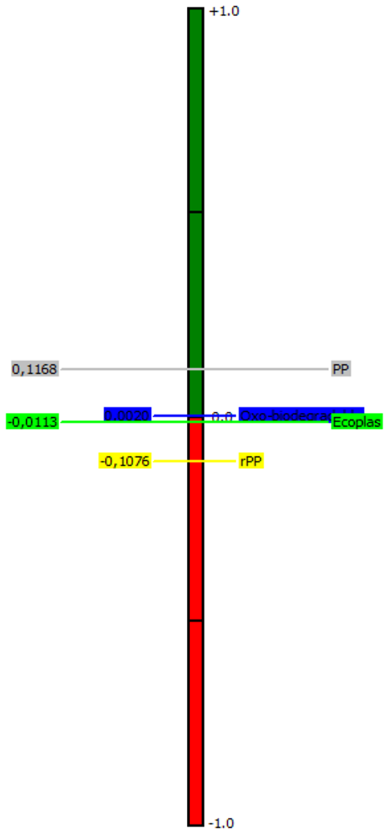


Fig. 2. Preference ranking of alternative packaging

Furthermore, to find out the criteria that have an impact on the Ecoplas ranking, a rainbow-PROMETHEE approach was used. Based on Fig 3. Result of Rainbow-PROMEHTEE, The visualization results of the most impactful criteria on the ranking of alternatives show that Ecoplas is still considered to have shortcomings in several criteria. The most dimensions that are considered to still need to be improved in the use of Ecoplas as an alternative flexible packaging are the ease of access to Ecoplas and consumer knowledge of Ecoplas. These criteria are the level of public awareness to use related types of alternative packaging (S2), the level of public ease of obtaining related packaging (S3), the level of frequency of use of packaging by the public (S4).

Meanwhile, in the economic dimension, the criterion that shows positive in the economic dimension is the preference of people to buy products with related packaging based on price (Ec). This shows the high commitment or desire of consumers to buy Ecoplas. This situation illustrates that in terms of price, Ecoplas has enough to compete with conventional for respondents. Ecoplas has a very strong assessment of the environmental dimension. The environmental assessment criteria show higher positive values than other criteria. Correspondingly, Ecoplas' technological dimension was rated quite well by respondents on the criteria of public preference for the level of packaging properties (T1) and public preference for packaging safety (T3). However, there are technological dimension criteria that Ecoplas must improve, namely public preference for packaging durability in maintaining product quality (T2).

4 Discussion

The sustainability performance of Ecoplas packaging is reviewed with the PROMETHEE approach through a comparison of the assessment of each parameter. PROMETHEE can produce an outranking-based ranking that is based on the relationship between alternatives through multicriteria techniques. The use of PROMETHEE can make it easier to develop and improve sustainability strategies that focus more on how a product can achieve sustainability [23].

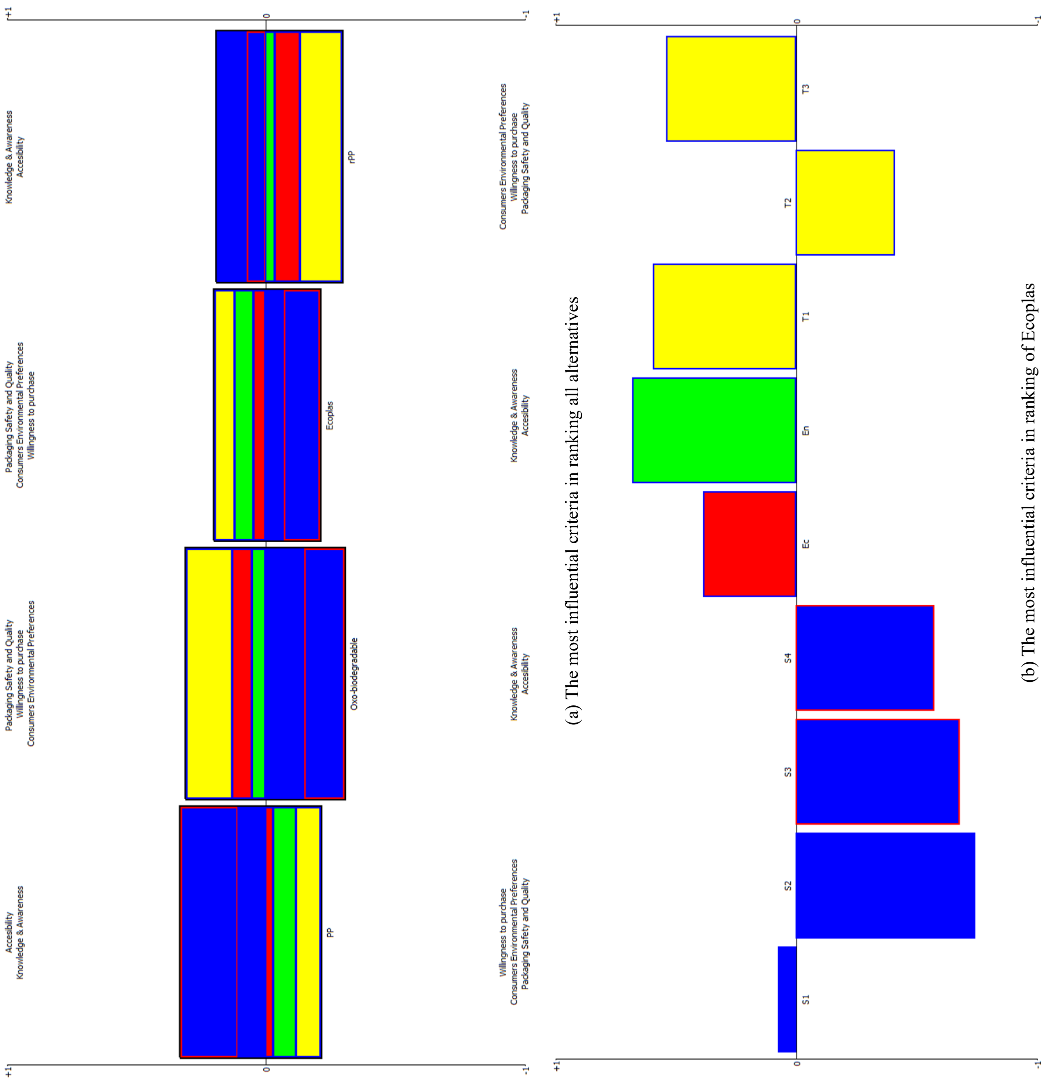
Fig. 2. Preference ranking of alternative packaging shows the results of the Ecoplas packaging PROMETHEE test against other types of packaging reaching a Phi value of -0.0113. The Phi value makes Ecoplas packaging have a higher sustainability performance than recycled PP packaging types. However, it is inferior to Oxo-biodegradable and PP in the case of its use for flexible packaging based on consumer assessment.

Basically, the Phi value is influenced by each value of each parameter. Therefore, the Phi value in Ecoplas packaging is due to the assessment of several criteria that the packaging is considered superior to r-PP or lower than PP and Oxo-biodegradable packaging types.

Each parameter of each aspect influences each other and determines the comparative ranking of packaging types. In the technology dimension, Ecoplas packaging is considered to have sufficient property conditions. This can be seen from the assessment of public preference for the level of packaging properties (T1) and public preference for packaging safety (T3) which obtained a positive phi value.

The level of safety in food by Ecoplas is also considered good by consumers with a value reaching 25.81% which is higher than the packaging from

 https://doi.org/10.1051/e3sconf/202449503003



(a) The most influential criteria in ranking all alternatives

(b) The most influential criteria in ranking of Ecoplas

Fig 3. Result of Rainbow-PROMEHTEE

recycling which has a value of 23.80%. However, the durability of Ecoplas packaging to maintain quality must be further improved as it only scored 24.38% which is lower than Oxium, rPP and PP. Physical and mechanical properties are interconnected and are the result of the underlying chemical structure of both biopolymers, additives, fillers, and their inter- and intramolecular interactions [49].

In addition, the criteria for public preference for packaging durability in maintaining product quality (T2) is considered low. Thus, it still has to improve its performance to be able to guarantee products for a long time. This is because the use of packaging basically aims to maintain both food and non-food products for a long time.

The low numbers of these property parameters are due to the fact that Ecoplas packaging material is derived from cassava which is a vegetable material. Packaging that contains plant-based materials tends to have low transparency, tensile strength and elongation. There are challenges in the functional properties of some bioplastics, such as thermal instability, low marketability, brittleness, low melt strength, high water vapor and oxygen permeability. Indeed, the low property numbers of Ecoplas packaging may limit the variety of its uses [16], [36].

Based on

Fig 3. Result of Rainbow-PROMEHTEE, parameter that affects the good enough Phi value of Ecoplas packaging is the environmental dimension. The parameter is the level of public preference to buy packaging based on the environmental benefits obtained (En). This level of consumer preference indicates a good commitment to consumers to choose packaging in terms of the benefits they receive.

Therefore, on the economic aspect, Ecoplas packaging tends to be acceptable to the public. Based on the respondents' parameter to buy products packaged with Ecoplas (Ec) material, this alternative packaging reached a value of 25.57%, higher than Oxo-biodegradable packaging. This shows that consumers have a good desire to choose Ecoplas as an alternative packaging that can compete with other packaging.

However, the level of accessibility to obtain Ecoplas packaging is considered to be difficult, reaching only 22.04%. This figure is much lower than the accessibility of PP, Oxium and recycled packaging. This indicates that although consumers tend to be receptive to Ecoplas packaging solutions, obtaining it in the distribution chain or its use in products with Ecoplas packaging tends to be more difficult to find. As a result, the use of Ecoplas packaging in products that are massively in the market is relatively low.

The uniqueness of this fact is people in developing countries are concerned about the ecosystem and want to play their part in a green environment through the green economy, including buying green products. Consumers in developing countries are likely to still be willing to pay an additional price if they compare the value against the cost of the impact to health, money, environmental damage by buying the green product [50].

The criteria for public knowledge about post-use packaging processing (25.11%) and public awareness to routinely use Ecoplas are still rated low (22.85%). This assessment is much lower than PP packaging and PP recycling which tend to be better known by the community. The reason is that the knowledge related to the social impact of Ecoplas is not sufficiently known to the community and the community's knowledge of post-use processing of Ecoplas by the community is not massively socialized.

5 Conclusion

The study showed that the use of Ecoplas packaging achieved a phi score of -0.0113, lower than PP (0.1168) and Oxobiodegradable (0.0020) packaging, but higher than r-PP (-0.1076). The positive sustainability criteria based on Ecoplas's consumer assessment are public preference for the level of packaging properties (T1), public preference for packaging safety (T2), public preference for buying packaging based on the environmental benefits obtained (En), public knowledge level of packaging processing after use (S1), and public preference for buying products with related packaging based on price (Ec). Sustainability criteria that must be improved by Ecoplas are the level of public awareness to use related types of alternative packaging (S2), the level of ease of obtaining related packaging (S3), the level of frequency of use of packaging by the community (S4), and public preference for packaging durability in maintaining product quality (T2).

The authors thanks to Greenhope Indonesia, The Ministry of National Development Planning/National Development Planning Agency of Indonesia, Indonesia's national coordination team for marine debris reduction (TKN-PSL), Gerakan PASTI Association, eco-friendly plastics monitoring coalition (KPPL-I) and all stakeholders for cooperative discussion and open-minded vision on this study.

References

[1] Indonesia National Plastic Action Partnership, *NPAP Indonesia: Policy Roadmap to Radically Reduce Plastic*. Jakarta: NPAP Indonesia, 2022.

[2] M. Nissa, C. T. Kusdiari, E. Elkarim, A. Ulfatunnisa, and A. P. Lestari, *Alur Material Sampah Plastik Fleksibel di DKI Jakarta*. Bekasi: Waste4Change, 2022.

[3] Plastic Health Coalition, "Plastic Pollution Is a Human Health Issue," 2021. [Online]. Available: www.plastichealthcoalition.org

[4] A. T. Sutanhaji, B. Rahadi, and N. T. Firdausi, "Analisis Kelimpahan Mikroplastik Pada Air Permukaan di Sungai Metro, Malang," *J. Sumberd. Alam Dan Lingkung.*, vol. 8, no. 2, pp. 74–84, Aug. 2021, doi: 10.21776/ub.jsal.2021.008.02.3.

[5] W. Abdelmoez, I. Dahab, E. M. Ragab, O. A. Abdelsalam, and A. Mustafa, "Bio- and oxo-degradable plastics: Insights on facts and challenges," *Polym. Adv. Technol.*, vol. 32, no. 5, pp. 1981–1996, May 2021, doi: 10.1002/pat.5253.

[6] T. Jiang, Q. Duan, Q. Duan, J. Zhu, H. Liu, and L. Yu, "Starch-based biodegradable materials: Challenges and opportunities," *null*, 2020, doi: 10.1016/j.aiepr.2019.11.003.

[7] T. D. Moshood, G. Nawanir, and F. Mahmud, "Sustainability of biodegradable plastics: a review on social, economic, and environmental factors.," *Crit. Rev. Biotechnol.*, 2021, doi: 10.1080/07388551.2021.1973954.

[8] V. Bauchmüller, C. Raj, and C. Michael, *Products for which biodegradation makes sense*. Nova-Institut für politische und ökologische Innovation GmbH, 2021.

[9] L. Filiciotto and G. Rothenberg, "Biodegradable Plastics: Standards, Policies, and Impacts," *ChemSusChem*, vol. 14, no. 1, pp. 56–72, Jan. 2021, doi: 10.1002/cssc.202002044.

[10] Ž. Stasiškienė *et al.*, "Challenges and Strategies for Bio-Based and Biodegradable Plastic Waste Management in Europe," *Sustainability*, vol. 14, no. 24, p. 16476, Dec. 2022, doi: 10.3390/su142416476.

[11] A. Ammala *et al.*, "An overview of degradable and biodegradable polyolefins," *Prog. Polym. Sci.*, vol. 36, no. 8, pp. 1015–1049, Aug. 2011, doi: 10.1016/j.progpolymsci.2010.12.002.

[12] S. Sable, D. K. Mandal, S. Ahuja, and H. Bhunia, "Biodegradation kinetic modeling of oxo-biodegradable polypropylene/polylactide/nanoclay blends and composites under controlled composting conditions," *J. Environ. Manage.*, vol. 249, p. 109186, Nov. 2019, doi: 10.1016/j.jenvman.2019.06.087.

[13] H. Hadiyanto, A. Khoironi, I. Dianratri, K. Huda, S. Suherman, and F. Muhammad, "Biodegradation of oxidized high-density polyethylene and oxo-degradable plastic using microalgae *Dunaliella salina*," *Environ. Pollut. Bioavailab.*, vol. 34, no. 1, pp. 469–481, Dec. 2022, doi: 10.1080/26395940.2022.2128884.

[14] A. Khoironi, K. Huda, I. Hambyah, and I. Dianratri, "Pengaruh mikroplastik polietilen dan oxo-degradable (Oxium) pada pertumbuhan Mikroalga Tetraselmis Chuii," *J. Ilmu Lingkung.*, vol. 19, no. 2, pp. 211–218, Aug. 2021, doi: 10.14710/jil.19.2.211-218.

[15] E. G. Shershneva, "Biodegradable Food Packaging: Benefits and Adverse Effects," *IOP Conf. Ser.*, 2022, doi: 10.1088/1755-1315/988/2/022006.

[16] K. P. Wijayanti, N. Dermawan, S. N. Faisah, V. Prayogi, T. Nugraha, and N. T. Listyorini, "BIO-DEGRADEABLE BIOPLASTICS SEBAGAI PLASTIK RAMAH LINGKUNGAN," *Surya Octag. Interdiscip. J. Sci. Technol.*, vol. 1, no. 2, 2016.

[17] P. Arjasa, E. Hartati, and S. Ainun, "Analisis Tingkat Ekonomi untuk Jenis Penutup Harian Alternatif di TPPAS Regional Sarimukti," *J. Rekayasa Lingkung.*, vol. 6, no. 2, 2018.

[18] Greenhope, "Company Profile." PT Harapan Interaksi Swadaya, 2022.

[19] ASTM International, "Standard Test Method for Determining Aerobic Biodegradation in Soil of Plastic Materials or Residual Plastic Materials After Composting (D5988 – 03)." ASTM International, 2019. [Online]. Available: https://www.astm.org/d5988-18.html

[20] E. Sembiring and Y. Novitasari, "DEGRADATION OF DEGRADABLE PLASTICS ON SEVERAL SOLID AND LIQUID MEDIA," *Third Jt. Semin. Jpn. Indones. Environ. Sustain. Disaster Prev.*, vol. 3rd, 2015.

[21] Z. Andreopoulou, C. Koliouska, E. C. Galariotis, and C. Zopounidis, "Renewable energy sources: Using PROMETHEE II for ranking websites to support market opportunities," *Technol. Forecast. Soc. Change*, 2017, doi: 10.1016/j.techfore.2017.06.007.

[22] M. Behzadian, R. B. Kazemzadeh, A. Albadvi, and M. Aghdasi, "PROMETHEE: A comprehensive literature review on methodologies and applications," *Eur. J. Oper. Res.*, 2010, doi: 10.1016/j.ejor.2009.01.021.

[23] A. Fauzi, *Teknik Analisa Keberlanjutan*. Jakarta: Gramedia, 2022.

[24] M. Gul, E. Celik, A. T. Gumus, and A. F. Guneri, “A fuzzy logic based PROMETHEE method for material selection problems,” *Beni-Suef Univ. J. Basic Appl. Sci.*, vol. 7, no. 1, pp. 68–79, Mar. 2018, doi: 10.1016/j.bjbas.2017.07.002.

[25] P. P. Das and S. Chakraborty, “Application of Grey-PROMETHEE Method for Parametric Optimization of a Green Powder Mixed EDM Process,” *Process Integr. Optim. Sustain.*, vol. 5, no. 3, pp. 645–661, Sep. 2021, doi: 10.1007/s41660-021-00173-8.

[26] L. Abdullah, W. Chan, A. Afshari, and A. R. Afshari, “Application of PROMETHEE method for green supplier selection: a comparative result based on preference functions,” *J. Ind. Eng. Int.*, 2019, doi: 10.1007/s40092-018-0289-z.

[27] O. Bozorg-Haddad, B. Zolghadr-Asli, and H. A. Loaiciga, *A handbook on multi-attribute decision-making methods*. in Wiley series in operations research and management science. Hoboken, NJ: Wiley, 2021.

[28] D. M. Khairina, D. Ivando, and S. Maharani, “Implementasi Metode Weighted Product Untuk Aplikasi Pemilihan Smartphone Android,” *J. INFOTEL - Inform. Telekomun. Elektron.*, vol. 8, no. 1, p. 16, May 2016, doi: 10.20895/infotel.v8i1.47.

[29] P. A. Lachenbruch, S. K. Lwanga, and S. Lemeshow, “Sample Size Determination in Health Studies: A Practical Manual.,” *J. Am. Stat. Assoc.*, vol. 86, no. 416, p. 1149, Dec. 1991, doi: 10.2307/2290547.

[30] M. Tosin, A. Pischedda, and F. Degli-Innocenti, “Biodegradation kinetics in soil of a multi-constituent biodegradable plastic,” *Polym. Degrad. Stab.*, vol. 166, pp. 213–218, Aug. 2019, doi: 10.1016/j.polymdegradstab.2019.05.034.

[31] C. M. Finzi-Quintão, K. M. Novack, and A. C. Bernardes-Silva, “Identification of Biodegradable and Oxo-Biodegradable Plastic Bags Samples Composition,” *Macromol. Symp.*, vol. 367, no. 1, pp. 9–17, Sep. 2016, doi: 10.1002/masy.201500156.

[32] G. Parker, *A Life Cycle Assessment of Oxo-biodegradable, Compostable and Conventional Bags*. United Kingdom: Intertek Expert Services, 2012.

[33] R. M. M. Abed, T. Muthukrishnan, M. Al Khaburi, F. Al-Senafi, A. Munam, and H. Mahmoud, “Degradability and biofouling of oxo-biodegradable polyethylene in the planktonic and benthic zones of the Arabian Gulf,” *Mar. Pollut. Bull.*, vol. 150, p. 110639, Jan. 2020, doi: 10.1016/j.marpolbul.2019.110639.

[34] F. & D. F. CTPA, *Recycled content used in plastic packaging applications*. British Plastic Federation, 2020.

[35] E. E. Ferg and N. Rust, “The effect of Pb and other elements found in recycled polypropylene on the manufacturing of lead-acid battery cases,” *Polym. Test.*, vol. 26, no. 8, pp. 1001–1014, Dec. 2007, doi: 10.1016/j.polymertesting.2007.07.001.

[36] N. I. Ibrahim, F. S. Shahar, M. T. H. Sultan, A. U. M. Shah, S. N. A. Safri, and M. H. Mat Yazik, “Overview of Bioplastic Introduction and Its Applications in Product Packaging,” *Coatings*, vol. 11, no. 11, p. 1423, Nov. 2021, doi: 10.3390/coatings11111423.

[37] H. Wang, D. Wei, A. Zheng, and H. Xiao, “Soil burial biodegradation of antimicrobial biodegradable PBAT films,” *Polym. Degrad. Stab.*, 2015, doi: 10.1016/j.polymdegradstab.2015.03.007.

[38] I. Kazulytė, “Packaging recycling and using of recycled raw materials in the production of packages, with an emphasis on hazardous chemical substances,” *Environ. Res. Eng. Manag.*, vol. 74, no. 4, pp. 19–30, Feb. 2019, doi: 10.5755/j01.erem.74.4.22148.

[39] M. Rapa *et al.*, “IMPROVEMENT OF SOME POST-CONSUMER POLYPROPYLENE (rPP) BY MELT MODIFICATION WITH STYRENE-DIENE BLOCK COPOLYMERS,” *Environ. Eng. Manag. J.*, vol. 16, no. 11, pp. 2615–2624, 2017, doi: 10.30638/eemj.2017.272.

[40] H. Maddah, “Polypropylene as a Promising Plastic: A Review,” *Am. J. Polym. Sci.*, no. 6(1): 1-11, 2016.

[41] A. R. Thakre, R. N. Baxi, D. R. S. Shelke, and D. S. S. Bhuyar, “Composites of Polypropylene and Natural Fibers: A Review,” *Nternational J. Res. Eng. IT Soc. Sci.*, vol. 08, no. 12, pp. 56–59, 2018.

[42] P. Tice, *Packaging materials. 3, Polypropylene as a packaging material for foods and beverages*. Brussels: ILSI Europe, 2002.

[43] A. Laapo, D. Howara, S. Kassa, H. Sultan, and Abd. Rahim, “A Multidimensional Approach to Assessing the Leverage Factors of the Sustainability of Seaweed Farming in Coastal Area of Parigi Moutong District, Indonesia,” *J. Aquac. Fish Health*, vol. 10, no. 3, p. 271, Aug. 2021, doi: 10.20473/jafh.v10i3.24281.

[44] T. Sukwika, D. Darusman, C. Kusmana, and D. R. Nurrochmat, “Evaluating the level of sustainability of privately managed forest in Bogor, Indonesia,” *Biodiversitas J. Biol. Divers.*,

vol. 17, no. 1, 2016, doi: 10.13057/biodiv/d170135.

[45] T. Sukwika and L. Noviana, “Status Keberlanjutan Pengelolaan Sampah Terpadu di TPST-Bantargebang, Bekasi: Menggunakan Rapfish dengan R Statistik,” *J. Ilmu Lingkung.*, vol. 18, no. 1, pp. 107–118, Apr. 2020, doi: 10.14710/jil.18.1.107-118.

[46] T. J. Pitcher *et al.*, “Improvements to Rapfish: a rapid evaluation technique for fisheries integrating ecological and human dimensions [a]: Improvements to rapfish,” *J. Fish Biol.*, vol. 83, no. 4, pp. 865–889, Oct. 2013, doi: 10.1111/jfb.12122.

[47] T. J. Pitcher and D. Preikshot, “RAPFISH: a rapid appraisal technique to evaluate the sustainability status of ®sheries,” *Fish. Res.*, vol. 49, no. 2001, pp. 255–270, 2001.

[48] A. Makan and A. Fadili, “Sustainability assessment of large-scale composting technologies using PROMETHEE method,” *J. Clean. Prod.*, vol. 261, p. 121244, Jul. 2020, doi: 10.1016/j.jclepro.2020.121244.

[49] R. M. S. Cruz *et al.*, “Bioplastics for Food Packaging: Environmental Impact, Trends and Regulatory Aspects,” *Foods*, vol. 11, no. 19, p. 3087, Oct. 2022, doi: 10.3390/foods11193087.

[50] S. Mustafa, T. Hao, K. Jamil, Y. Qiao, and M. Nawaz, “Role of Eco-Friendly Products in the Revival of Developing Countries’ Economies and Achieving a Sustainable Green Economy,” *Front. Environ. Sci.*, vol. 10, p. 955245, Jul. 2022, doi: 10.3389/fenvs.2022.955245.