The Packaging Index (PIX) - a proposed methodology for packaging assessment and comparison

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Abstract. The use of packaging and the related environmental consequences are increasingly under discussion. Despite its advantages, packaging has become the focus of public concern, mainly due to insufficient or inadequate handling of packaging waste. There is plenty of research regarding the sustainability of packaging options; however, multiple quantifiable characteristics have never been combined into a single indicator. The proposed Packaging Index (PIX) offers a tool to evaluate and compare different packaging options for the same product. To achieve these goals, the current evaluation criteria for the PIX are i) packaging quantity, ii) recyclability, and iii) environmental footprint. The resulting assessment is displayed as best to worst case scenario, with a single score for simple comparison. Using life cycle thinking, the environmental footprint of the packaging is accounted from cradle-to-grave. The suggested visualization of the PIX represents a practical comparison of diverse packaging alternatives within a defined product group. In the illustrative example, the PIX serves as an instrument to compare available bags found commonly in German online-retail. This example also shows that the PIX can analyze the packaging value chain from diverse industries and contributes to the circular economy. The usability of the PIX extends from communication (such as customer relations) to other fields like internal supply chain optimization. Lastly, we present the communication strategy of the PIX aimed at two different user groups.

1 Introduction

Packaging is an essential element of many supply chains. It fulfills the purpose of protecting the produced goods from any environmental influences that could cause damage or loss [1]. In addition, especially for consumer products, it carries important information and serves as a marketing surface. Despite these important attributes, the environmental impacts caused by packaging solutions raise increasing concerns among consumers and legislators [2–4]. From the use of fossil resources, over to low recycling rates, and packaging entering the environment, many issues related to the use of packaging have been detected [5, 6]. This has

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lead to unprecedented consumer awareness and demand for sustainable packaging solutions. Thus, the pressure to implement more sustainable solutions increases steadily [3].

Though, assessing packaging as a whole is a complex problem and hard to understand for all parties involved [7]. The variety of problems, their causes, and effects are too broad and difficult for non-experts to understand. Likewise, misinformation does the rest to confuse consumers, users, and providers. Many approaches trying to solve this issue have already been established [8–11]. In the existing approaches, several environmental topics are addressed. Nevertheless, none of the known evaluation methods combine different evaluation criteria into a single-score indicator. To the best of our knowledge, and based on an extensive literature review, there is no established indicator that combines multiple indicators into a single score for packaging. A single score is easy to understand without previous expertise, analogous to the *nutri-score,* which is proven to be an efficient tool in public health nutrition [12]. Here, we propose a Packaging Index (PIX) that combines and provides valuable environmental information to producers, users, and consumers. The main target of the PIX is to build a framework for such a tool, and to offer a comprehensive indicator for all involved stakeholders of the packaging industry.

2 Methodology

The developed Packaging Index (PIX) offers an indicator as a tool to evaluate and compare packaging for products with the same functional unit. An indicator that is easy to understand, but at the same time includes and combines important environmental criteria. The PIX enables users the possibility to reduce packaging consumption, appraise the recyclability, and minimize the overall environmental footprint. To achieve these goals, the evaluation criteria of the PIX are (1) packaging quantity, (2) recyclability, and (3) the packaging environmental footprint. The environmental footprint is evaluated with Life Cycle Assessment (LCA). Consistently, the packaging is accounted from cradle-to-grave. Within the system boundaries of the PIX five points of entry along the supply chain are identified and accounted for.

For the PIX calculation we suggest three main criteria for the assessment:

- **Amount of packaging per unit (F1)**

The amount of packaging is compared with the use of a functional unit within a product group. The functional unit indicates the mass, amount, or units of product that the user wants to compare. This results in a packaging-to-product ratio, and by doing so the reusability is also accounted for. F1 does not consider the type of material, only the mass. The packaging-to-product ratio is weighted and the resulting F1 is a value between 0 and 100. With this, 0 is awarded to the worst-case representing the highest value of the packaging-to-product ratio, and 100 representing the best-case.

- **Recyclability (F2)**

Recyclability is calculated to estimate the potential of the packaging to be used in a circular economy. The recyclability is calculated for each packaging individually, according to cyclos-HTP guidelines [13]. Moreover, the recyclability is calculated within the recycling infrastructure and available recycling paths. Here the design, material(s), colour, separability, and labelling play an important role in the assessment. As a result, the packaging is rewarded with a score between 0 and 100. The F2 equals the value of the recyclability, where 100 indicates a full recyclability of the packaging.

Factors such as recycled content and degradability (i.e. composting) are included as disposal routes and influence the environmental footprint (F3) results. For example, the recycled content is taken into account, by performing the corresponding allocation of the recycled material in the production and the end-of-life. As for degradability and e.g. biodegradable plastics, the discussion of whether or not they truly have a benefit to the environment is still unclear. Therefore, at a later stage of research in the packaging industry and alternative materials, an indicator could be included in the calculation, e.g. when there is more knowledge about the biodegradability of plastics.

- **Environmental Footprint (F3)**

The environmental footprint (EF) is calculated from cradle-to-grave using LCA. Within the calculation of the EF, the material feedstock, resource use, and recycled content are all considered. The end-of-life scenario of the packaging is based on the calculation of F2, which gives an indicator of the recyclability, as well as the incineration and landfilled shares. These end-of-life scenarios are country and region specific. So far, the PIX has been calculated and assessed within the German recycling infrastructure. The different impact categories of the LCA are normalized and weighted according to the EF 3.0 method recommended by the European Commission [14]. With this method, all relevant environmental burdens and impact categories are taken into account. Equally to the calculation of F1, the use of a functional unit serves to compare different presentations of the same product. Likewise, the F3 is presented as best and worst-case scenario. The packaging is rewarded with a score between 0 and 100, with 0 being the worst-case representing the highest EF, and 100 representing the best-case or lowest EF.

The LCA model includes the mass of the packaging (F1) and the recyclability (F2). Nevertheless, in the PIX, mass and recyclability are present as independent indicators. By uncoupling the results from the EF calculation, a broader analysis is presented to the user. Furthermore, these multiple quantifiable characteristics are combined into a single indicator. This allows the decision or choice of packaging to be based on a single overall score supported by three individual criteria.

Due to the approach of the calculation of best and worst scenarios, packaging options score between 0 and 100 in the individual indicators (F1-3). However, the overall PIX is a single score that indicates best and worst practices within the case of study. This PIX score is suggested to be the mean value of the three abovementioned criteria, which designates equal relevance to each criterion in the assessment of the eco-friendliness of the packaging.

To achieve a comparison, at least three packaging options for the same product with the same functional unit must be evaluated. Lastly, the PIX allows comparing packaging options and portfolios; if a “no-packaging" solution is available, this can be included in the assessment. It is also important to mention that the functional unit does not include the performance of the packaging, e.g. how well is the product protected, or for how long.

2.1 Graphical representation

The graphical representation of the score is proposed in the shape of a circle. On the outside each individual criterion (F1, F2, and F3) is accompanied by a traffic light colour pattern. In the centre of the circle stands the overall PIX score. The methodology and suggested presentation of the PIX is outlined in Figure 1.

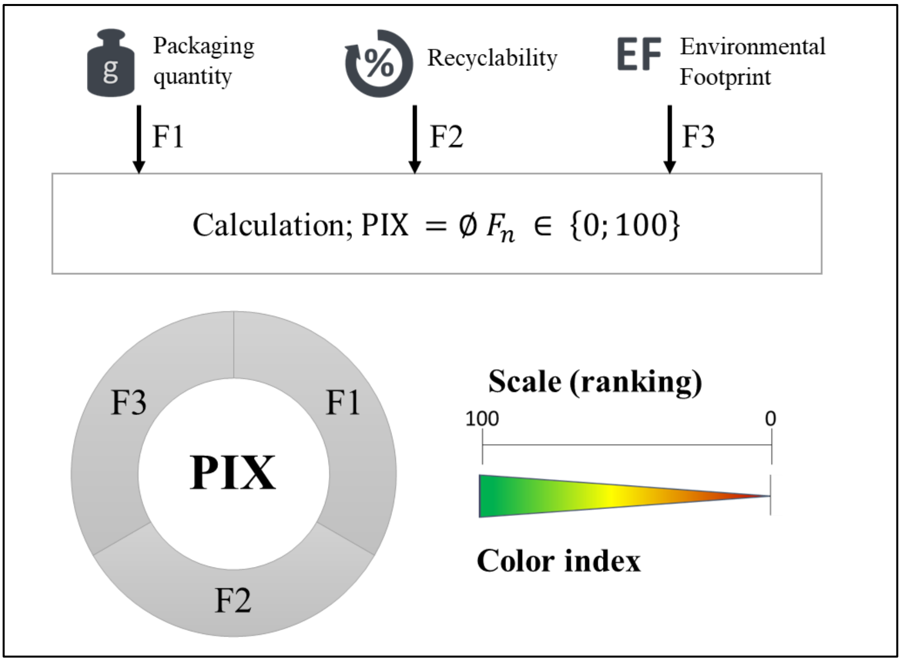

Figure 1: Graphical methodology of the PIX calculation

3 Illustrative example and communication strategy

The PIX can be used to analyse packaging solutions at any life stage, and enables a holistic assessment of the entire supply chain. Therefore, we distinguish between two user groups: the end-user or consumer at e.g. the point-of-sale, and users from industry and academia. Accordingly, the use of the PIX can support the communication between companies (B2B) e.g. for portfolio assessment and internal communication, and with customers (B2C).
Industry and academia tend to prefer analysis and decision-making based on multiple aspects and require more detailed information. For B2C communication, illustrations and a single-score assessment is preferred. For this reason, we present the communication strategy of the PIX, which is aimed at two different user groups.

To exemplify the use of the PIX, an illustrative example is performed for online-retail packaging bags found commonly in the textile industry in Germany. The study included seven packaging solutions that differ in material, feedstock, recycled content, reusability, and weight. The functional unit is the packaging needed for the shipping of 1 T-shirt. In the following example, we present three PIX scores out of the seven assessed packaging bags. The results are displayed in the suggested PIX outline, and according to the communication strategy of the different user groups. These are shown in Figures 2 and 3, respectively.

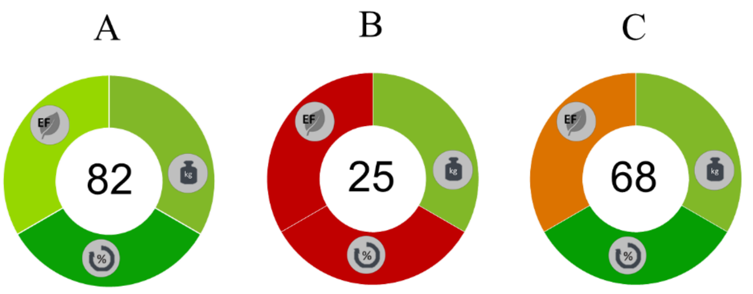

Figure 2: Examples A, B, and C of displayed PIX single-score for textile packaging. Communication strategy: B2C. User: consumers at the point-of-sale.

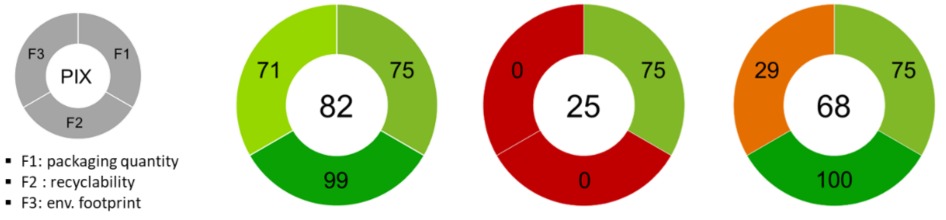

Figure 3: Examples A, B, and C of displayed PIX results for textile packaging. Communication strategy: B2B, internal. User: industry and academia.

Within this example, packaging **A** represents a plastic bag made from 100% recycled plastic, packaging **B** is a bag made from biobased plastic material, and **C** represents a bag made from virgin LDPE (low-density polyethylene). In Figure 2, the end-user (B2C communication strategy) quickly exemplifies the best option in the comparison. In the second representation, the individual rankings according to the environmental criteria are presented in more detail.

We can observe, that packaging **A** scores the highest overall PIX, with a score of 82. While packaging **B** can be considered the worst solution within these three examples, with a PIX score of 25. Here packaging **B** scores a 0 in recyclability, and the highest EF value which awards a 0 in the third criterion. We can also observe that the three selected examples have the same packaging-to-product ratio (F1), which indicates the same packaging weight. This results in the same score in criterion F1, where a score of 75 indicates that there is at least one packaging alternative with a better score (of 100), which was awarded to the lowest weight.

In summary, the PIX addresses three major points when evaluating the sustainability of packaging: (F1) packaging quantity, (F2) recyclability, and (F3) environmental footprint. It also includes design aspects like colour and material feedstock (primary vs. secondary, biobased vs. fossil, mono-material vs. composites, etc.). Moreover, the PIX categories are not absolute numbers, PIX is always relative to other packaging fulfilling the same packaging task. Thus it is possible to analyse packaging of a specific packaging portfolio according to individual criteria, or to simplify the result by presenting a single score.

4 Summary and conclusions

The evaluation criteria of the PIX are (1) packaging quantity, (2) recyclability, and (3) the packaging environmental footprint. The resulting assessment is displayed as the best to worst-case scenario, using a single score for simple comparison. This simplifies the comparison results and provides an easy-to-understand indicator. The proposed visualization of the PIX illustrates the comparison of diverse packaging alternatives, by displaying the three aforementioned criteria and the overall PIX single score on a scale between 0 and 100. Lastly, we demonstrate that the PIX can assess the environmental effects of packaging in a more comprehensive way than only LCA. This is done by offering two communication strategies and their respective graphical representation according to the user group.

There are many indicators and factors that influence the sustainability of packaging. For example, the motivation behind this debated topic often lies in the well-known environmental issue surrounding marine litter and plastic debris. There is research being done to develop a framework and include the impact of plastic emissions into LCA [15, 16]. However, a standard indicator to address these issues is not available, and including such an indicator in the PIX is not possible, yet. This also applies to the biodegradability of packaging materials, in particular of biobased plastics, we can only assess indicators that are both investigated and quantifiable. Based on further developments, other quantifiable evaluation criteria (F*n*) could be included and the weighting adjusted. The PIX is designed to be modular and adjustable based on upcoming knowledge and the development of packaging alternatives.

The proposed PIX provides stakeholders with comprehensive and easy-to-use information about the quantifiable environmental burdens of packaging. Moreover, when applying the PIX methodology and proposed graphical representation, the important environmental information is translated into a single score accompanied by a colour index, for easy visualization of the results. The user can profit from the PIX in several ways. For example, the indicator can be used as a benchmark tool to compare packaging alternatives. It can also be used to analyse and optimize the supply chain accordingly. The PIX can therefore support eco-design measures and help companies with the transformation towards a more circular economy, which becomes relevant as governments start to increase regulations on packaging limitation and waste reduction. The communication strategy of the PIX is aimed at two different user groups. Accordingly, the use of the PIX can support communication between companies (B2B) and with customers (B2C). The PIX can also be used in research and academia when analysing and comparing packaging alternatives. The main advantage of the PIX is the condensation of environmental criteria into one single score. With this methodology, three main criteria assessing the eco-friendliness of packaging is combined. Moreover, the results are based on scientific methods such as LCA and the recyclability calculation. Consequently, this method invalidates assumptions of intentional or unintentional greenwashing in the packaging industry.

Due to the core environmental information behind the PIX score, the results can potentially be used for internal and external purposes, as well as to communicate the information of packaging solutions. It can help reduce packaging consumption, select higher recyclability options, and minimize the overall environmental footprint. Thus, it provides the user with a tool for environmental management in the packaging field. Lastly, the PIX score methodology has already been tested in studies comparing packaging alternatives in the food industry, hygiene sector, and online retail, which proves its transferability and application.

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