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A multicriteria method for assessing the eco-performances of food packaging

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Abstract: The paper is aimed at illustrating the assessing method of the food packaging sustainability, in terms of functional, communicative and environmental criteria. The project is funded by the Piedmont Region and involves several research units belonging to different institutions. The Research Unit of Industrial Design of DAD (Department of Architecture and Design, Politecnico di Torino) has the scope of elaborating the packaging assessing method by identifying the current market trends of food packaging and to outline a common reference to improve life cycle packaging design. The paper shows the calculating procedure of several criteria to evaluate the overall sustainability of food packaging respect to the current market situation.

Keywords: food packaging, environmental life cycle performances, evaluation system and method, packaging end-of-life treatments

1. Introduction

The paper deals with a multidisciplinary research Poliedro (Pollenzo Index Environmental and Economics). This research is aimed at developing a sustainability index able to evaluate at the same level, the environmental, social and economic variables that influence the performances of the agri-food product throughout its entire life cycle. In other words, Pollenzo Index would be a single score

that summarize and evaluate the agri-food performances on a scale of five ranges, that could be adopted by the local producers for assessing the sustainability of their product and manufacturing processes and, at the same time, that could be useful for the consumer during the choice of more sustainable agri-food products.
Within this project, a specific work-package (which is carried out by Research Unit of Industrial Design DIPRADI, Department of Architecture and Industrial Design, Politecnico di Torino) is focused on the food packaging, with the purpose to outline a multi-criteria methodology for assessing the sustainability level of the food packaging which must be integrated into the wider Pollenzo index.
Usually packaging sustainability is evaluated by taking into account mainly environmental criteria, with very well-known indicators, such as Global Warming Potential and Gross Energy Requirements, and by forgetting others important aspects, such as functional, communicative requirements that have to be satisfied by a food packaging. Consequently the research has been focused on the relationships between the environmental and functional and communicative requirements [17].
Environmental requirements related to resources and energy consumption, to waste generation and air emissions. Functional requirements linked to the need of proper use of the packaging, and communicative requirements concerning the need to recognise and identify the food content [13].

2. Food Packaging State of the Art

According to this goal, the research has been started from an analysis of the state of the art of the food packaging. Currently the main criticisms concerning the packaging are due the its short life, and to the fact that packaging waste represent about the 30% in mass of the total Municipal Solid Waste (MSW) produced yearly in the EU countries [1]. In order to tackle this problem, preventive strategies for increasing the recyclability potential of the constituent materials and eco-design guidelines for improving the environmental life cycle performances of the packaging have emerged [2].
These strategies were addressed in the EU Directives 94/62/EC - 2004/12/EE, which has led to the creation of national consortia for the management of packaging wastes, but have not yet yielded the expected results. At the European level, the production of packaging waste per capita is increasing despite of the rising of recycle percentage, highlighting how the prevention practices are not yet effective [3].
Moreover numerous LCAs about food packaging are available, but generally they do not take into account the existing relationships between environmental, functional and communicative aspects that need to be satisfied throughout the packaging life cycle.

3. Method used for defining multi-criteria evaluation system of the food packaging

On these assumptions, by adopting a life cycle thinking approach, the research has been carried on with an overview of the food life cycle within its packaging (Fig. 1). From this comparison, it can be underlined that while the phases of production, packaging, transport, purchase and consumption of the product can be directly controlled by the agri-food producers, the pre-production and end-of-life phases are the responsibility of others players, who are involved in the life cycle. Consequently the developed method has been firstly focused on those aspect that are directly controlled by the food producers and, secondly, has been extended to include other phases that are not under direct control of the food producer.

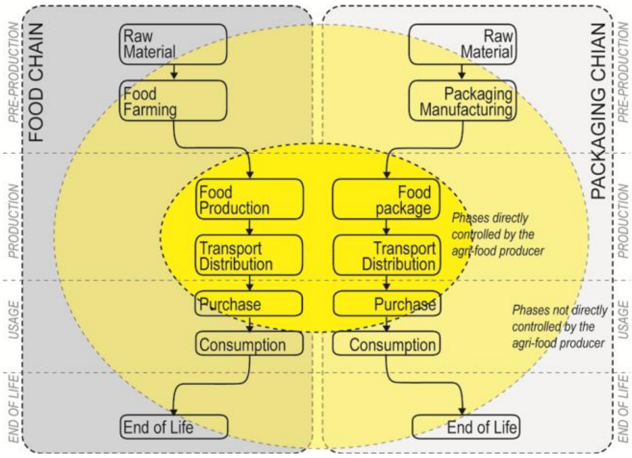

Fig. 1. Comparison between Packaging and Food life cycles with the highlighting of the phases under direct control of the food producers.

In order to define the multi-criteria evaluation of packaging performances, the used method in the research has been divided into the following steps:

- selection and analysis of the food product sample,
- identification of the criteria that are included into the packaging assessment;
- conversion of criteria in score indicator which aims at representing the packaging performance in a scale of 1 to 5: 1 = very bad, 2 = bad, 3 = average, 4 = good, and 5 = excellent. These are represented on a spider graph.

4. Selection of the Food Packaging Case Studies and Packaging Analysis

The analysis has begun with the analysis of three case studies: chocolate, alcoholic beverages and meat, which are representative of the principal agri-food chains in the Piedmont region. For each case study, a sample of several food packaging has been selected not aiming at representing the market share of the products, but at highlighting the different packaging design possibilities. Moreover the sample was built in order to compare products that come from medium-sized production plant of the Piedmont region with other products easily available on the market.

For the three case studies, 61 types of packaging were analyzed (Table 1). Since there are substantial differences among packaging, the case studies have been split into sub categories in order to perform consistent comparison.

Case studies	Sub category	Number of packaging	Sample per case study
Chocolate	Creams	6	25
	Bars	11	
	Chocolates	8	
Alcoholic beverage	Wine	12	24
	Beer	12	
Meat	Cured meat	5	12
	Fresh meat	5	
	Cooked meat	2	

Table 1. Packaging sample description

Following this, each product included in the sample was investigated on the basis of a common structure in order to identify functional, environmental and communicative criteria (Fig. 2).

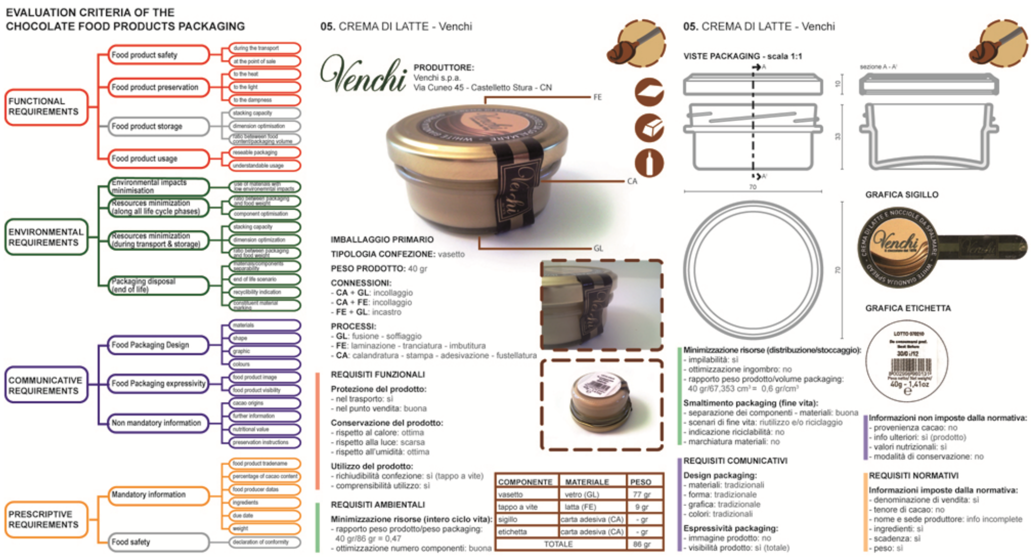

Fig. 2. Analysis perform for each chocolate food packaging of the sample

The preliminary analysis of the food packaging of the three case studies shown that they are very different for their material mix (Fig. 3).

It is important to underline that secondary and tertiary packaging were not taken into account due to the difficulties to collect direct data. Only in the case of the alcoholic beverage the secondary packaging was included in the elaboration.

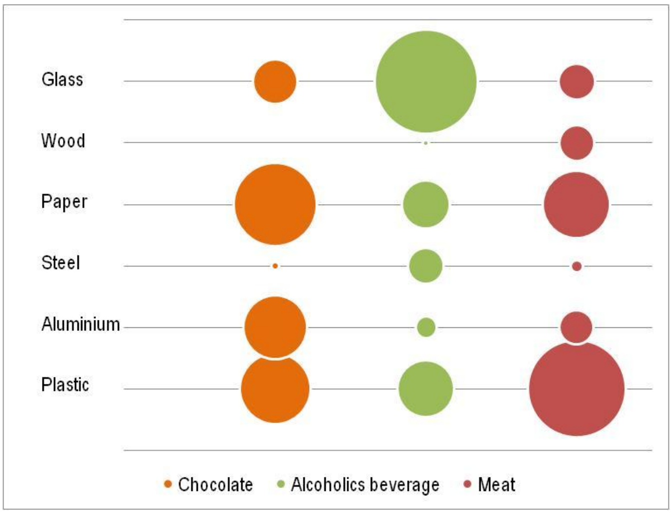

Figure 3. Packaging sample, material mix

Chocolate case study has been selected to shows the methodology because it is characterized by the highest variability of material mix, shapes and sizes. This case study has been split in the three subcategories that are chocolate bar, cream and chocolates. That sub categories are really different from the point of view of the complexity, mass and material mix(Fig. 4).

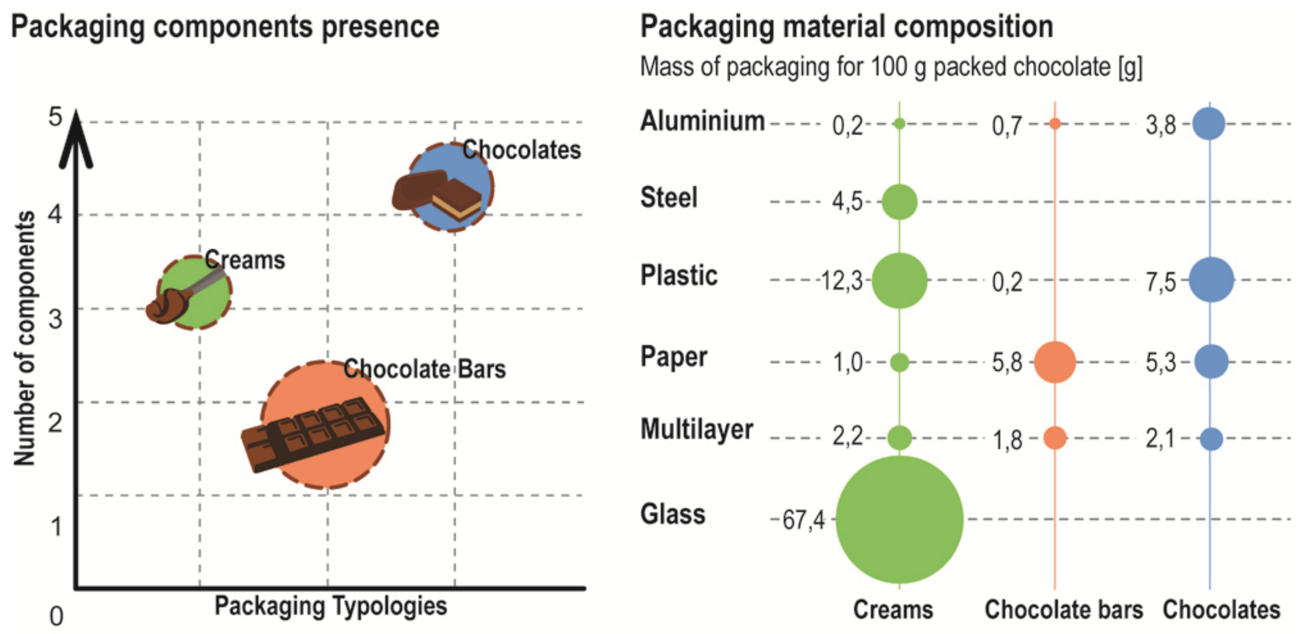

Fig. 4. Chocolate Packaging complexity in function of the component number and the material mix composition

5. Requirements - criteria identification

After the collection of the sample the research has been focused on the requirement identification that are used as evaluation criteria. These requirements should be classified in two groups:

- *quantitative requirements*, that are linked to the packaging performances, such as the Global Warming Potential (GWP) and the Gross Energy Requirements (GER).
- *qualitative requirements*, which are connected to the packaging functions are evaluated on dichotomous scales (yes/no) to define the presence of the specific function.

For the elaboration of environmental performances the SLCA (Streamlined Life Cycle Assessment) was performed. This is a widespread methodology used for the analyses of packaging [5]. Instead, for the identification of the functions the needs/requirements/performances method has been adopted. This methodology was conceived in the Industrial Design Degree Course (1^Faculty of Architecture, Politecnico di Torino) where man, or rather the end-user, is at the centre of the project. [12]

The selected requirements have been split in three category as described hereinafter. (Table 2) :

1) **Environmental Criteria:** this group involves requirements that are related to the environmental issues, such as the GWP and GER performances. Moreover other qualitative parameters are added to describe specific functions that are not included inside the SLCA indicators, such as component/materials separability (in order to allow the collection of the different materials), the chain of custody (the adoption of an environmental responsible management of raw material that is certified such as FSC or PFC certification) the reusability (criterion based that analyze if the packaging could be reused for the same or other purposes) and the potential recyclability.
2) **Functional criteria:** in this group are analysed requirements such as: the stacking capacity (the ability of the packaging to be stacked), the resealability (the possibility to open and close the packaging several time). Beside to these criteria the complexity (number of components) and the lightness (given by the ratio between packaging and food weight) are also included.
3) **Communication criteria:** in this group there are criteria to assess the communicative aptitude of the packaging. The requirements are: the preservation method (the presence of information for the

costumer about the correct handling of the product), the nutritional value (that help the users to focus attention on the correct nutrition), the origin of food (into the acquisition of raw material, the food farming phase or the food production), the packaging disposal instructions.

In addition, other criteria are under development with the aim to focus the attention on the packaging design aspects. By analysing the material, shape, colours of the packaging sample, it will be possible to argue if a packaging design is common or not common in comparison with the other packaging of the same category. Adopting this method it will be possible to understand if design innovations can have good or bad influence on sustainability.

Table 2. List of criteria selected for the packaging sustainability assessment.

Field	Criteria	unit
Environmental	GWP (Global Warming Potential)	gCO2eq
	GER (Gross Energy Requirements)	MJ
	Potential recyclability	% (mass of material to recycling)
	Separability	% (number of components that allow separation)
	Chain of custody	Y/N
	Presence of identification code	Y/N
	Reusability	Y/N
Functional	Stacking capacity	Y/N
	Resealability	Y/N
	Complexity	n (number of components)
	Lightness	% (food and packaging mass ratio)
Communicational	Preservation method	Y/N
	Nutritional value	Y/N
	Packaging disposal instructions	Y/N
	Origin of food	Y/N

It is important to underline that the environmental requirements (Table 2) that are included in the assessment method are suitable for each case study, nevertheless functional and communicative requirements have to be considered specific of the chocolate case study.

6. The Streamlined Life Cycle Analysis

The SLCA analysis has been carried out by calculating two typical LCA indicators, namely:

- GWP (Global Warming Potential): is an indicator that evaluates the emission of all gases that contribute to the greenhouse effect (such as carbon dioxide, methane, etc.). This indicator, also known as the Carbon Footprint is expressed in kilograms of CO2 equivalent and it is calculated by conversion factors defined by the IPPC [6]. The only fossil component is calculated according to the PAS 2050 [7] guidelines.
- Embodied Energy or GER (Gross Energy Requirement) is an indicator, expressed in MJ or kWh, of the total energy consumed throughout the life cycle of a functional unit of the product/service. In

short, with this indicator the amount of energy consumed in packaging production processes are counted within the energy required to produce fuels used in the processes and transport phases[18].

These indicators are used because they are able to describe the potential impacts on the two environmental sectors that are currently considered of major interest, the global warming and the energy resources depletion. Moreover they are easy to be communicated to non-experts audience.

For the calculation of the LCA indicators, a specific reference database was prepared by collecting data from several databases such as the Cambridge Eco-Selector (Granta Design Limited) and from LCA studies of the European producers. (including Plastics Europe for plastics, the EAA for Aluminium, FEFCO - for paper). The impact calculation is based on mass allocation [8] while further information on processes have been hypnotized according to the packaging shaping technologies [14].

To evaluate packaging end of life the potential recycling rate has been considered as an indicator itself The official data of the Italian Consortium for Packaging Waste Management [9] (Table 3) is used as reference to elaborate the potential recycling of packaging.

Material	End of life scenario (CONAI data)			End of life scenario (without recycling)		
	Recycling	Incineration	Landfill	Recycling	Incineration	Landfill
Steel	71%	0%	29%	-	0%	100%
Aluminium	72%	6%	22%	-	20%	80%
Paper	79%	8%	13%	-	39%	61%
Wood	60%	3%	37%	-	7%	93%
Plastics	34%	36%	30%	-	55%	45%
Glass	68%	0%	32%	-	0%	100%

Table 3. End of life scenario definition and the corresponding scenario for not recyclable component.

Since not all the packaging components are actually recyclable, the degree of recyclability of each packaging has been elaborated on the basis of the real recyclability. Therefore the average end-of-life scenario for the non-recyclable components was elaborated by allocating the recycling potential to the other two waste treatment (Table 3). For the specific case of multilayers, that do not fit any material category, the average scenario of the Italian average Municipal Solid Waste was used [10]. This scenario provides that approximately 12.1% of the MSW produced is sent to incineration while the remainder waste, that is not recyclable, is sent to landfill.

7. Conversion of the multi-criteria assessment in a single index

For each indicator the evalutation of the sample have been adopted as reference for the assessment method. A set of 5 range has been identified to transform the evaluation of each criteria in a single score. This normalization makes it possible to set the score scale of each criteria as a dimensionless value in order to compare different criteria among them. Two different calculation procedure are needed to convert quantitative and qualitative criteria in the five range.

7.1 Conversion of quantitative criteria

For the quantitative indicators the range have been set by calculating the mathematical average of the sample. The upper and lower average values with the maximum and minimum recorded have been used as reference value to subdivided sample results in the 5 range (Fig.5), that are:

- average values: values included between the upper and lower average of the samples analysed. This value equals to 3 – Average;
- values above average: values included between the upper average and the maximum value analysed. This value is equivalent to 4 – Good;
- values below lower average: values included between the lower average and the minimum value analysed. This value equals to 2 – Bad;
- values lower than the minimum analysed. This value equals to 1 - Very Bad;
- values higher than the maximum analysed. This value is equivalent to 5 - Excellent.

The score from 1 to 5 can be reversed on the basis of the criteria under analysis, following the “more is better” principle, e.g. the potential recycling or by adopting the “less is better” principle e.g. the quantitative attribute of carbon footprint.

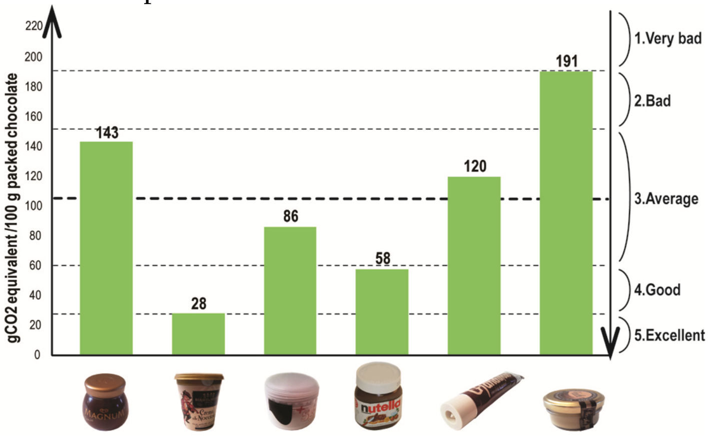

Fig 5. From quantitative analysis to qualitative judgment

7.2 Conversion of quantitative criteria

For qualitative indicators, it is not possible to calculate averages because of the dichotomous values (Yes/No) of the criteria evaluation. In this case, the assessment of the qualitative criteria is based on the Kano theory [16], which differentiates several kind of definitions for functions, that in the Kano theory are defined attributes. From Kano's theory only *must-be* and *attractive* quality attribute have been taken into account. These two definitions helps to differentiate which packaging function is really needed, and which could be identified as a sign of innovation or attractiveness. The Kano's attributes usually need the customer investigation to be defined [4], but in this case they are deducted by the analysis of the sample. In fact by calculating the percentage of how many packaging fulfil a function within the sample is possible to define in which case the functions are a *must-be* or *attractive*. In other words, if the majority of the sample fulfil the function it means that the function is a *must-be* attribute, and on the contrary, if not all the packaging of the sample fulfil the requirement it means that function is an *attractive* attribute. These two definitions allow to elaborate the five range as described in Fig.6.

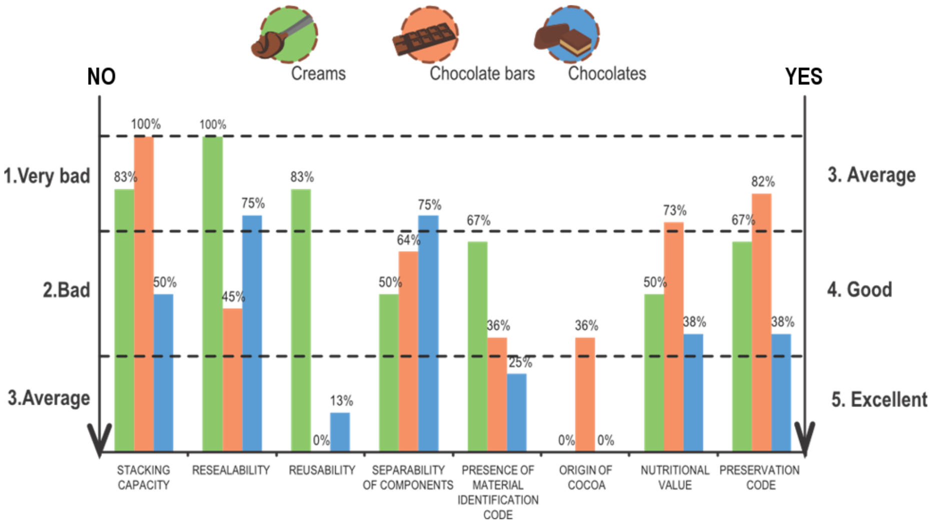

Fig 6. From qualitative criteria to the score conversion. The score is calculated by the sample percentage

In the case of all chocolate bars all packaging in the sample perform the function *stacking capacity*, therefore if the packaging that it is wanted to be analysed fulfils this function, the assigned score will be equal to 3 (average), because this criteria is a *must be* function. On the contrary, in the case of the *reusability* of the chocolate bars, no packaging in the sample fulfil the requirement therefore if the analysed packaging fulfils this function, the result is 5 (excellent), because this criteria is conceived as an *attractive* function for chocolate bars.

7.2 From criteria to the spider graph

Thanks to this ranges, it is possible to normalize all the criteria into a dimensionless score that can be averaged in a single score and represented in a single graph. As required by the Poliedro project, the last step is the definition of an evaluation weighting systems for the various criteria. The final part of this research is still ongoing. Furthermore, all the criteria adopted up to now into the packaging evaluation method, are easily described and shown in a "spider" graph (Fig. 7). By using this representation of the results, and thanks to the fact that all the measurement are translated in a score from 1 to 5, the evaluation carried out should be a useful tool during the packaging design stages for choosing among several design solutions of new packaging..

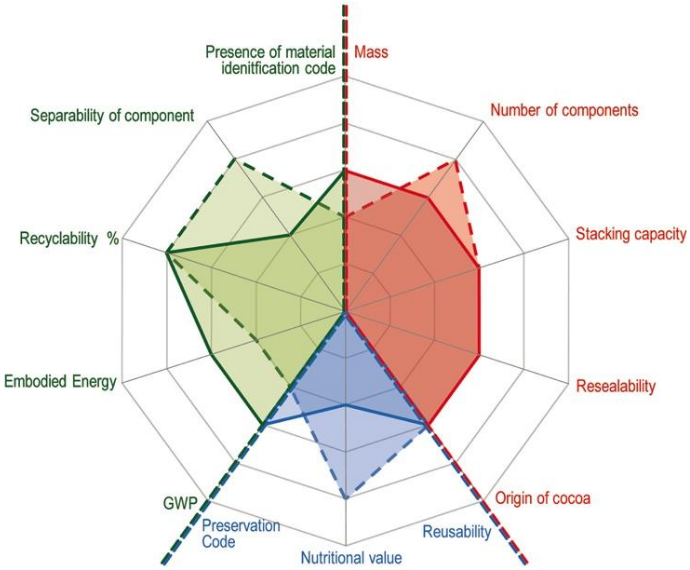

Figure 7. Representation of the results as a "spider" graph

8. Conclusions

The paper illustrates the results carried out up to date into the definition of the multi-criteria evaluation method of the food packaging.

The multi-criteria evaluation system that can be an useful tool for several scopes:

- to convert the packaging sustainability in a scale of 5 ranges that will be included in the wider Poliedro Index;
- as a tools useful for the agri-food producer, because by outlining a product groups reference, any packaging can be submitted to this assessment in order to determine its position in the current market situation.
- as an instrument for supporting designers.

An automatic procedure to elaborate the indicators, that is the next steps of research, will be developed. The procedure will have the aim of averaged all the indicators in a synthetic score by which is possible to set the thresholds to define the conformity of packaging in the Poliedro project criteria.

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Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/waste_generation_management/generation (accessed 05/07/2012)
2. Helen L.Defining product stewardship and sustainability in the Australian packaging industry. *Environmental Science & Policy* **2005**, 8, 45–55
3. http://www.eea.europa.eu/data-and-maps/indicators/generation-and-recycling-of-packaging-waste/generation-and-recycling-of-packaging-2 (accessed 10/03/2011).
4. Williams H., Wikstrom F., Lofgren M., A life cycle Perspective on environmental effects of customer focused packaging development. *Journal of Cleaner Production* **2008**, 16 , 853 – 859.
5. Verghese K. L., Horne R, Carre A.; PIQET: the design and development of an online ‘streamlined’ LCA tool for sustainable packaging design decision support. *International Journal Life Cycle Assess*, **2010**, 15, 608 – 620.
6. IPCC Climate Change, IPCC Fourth Assessment Report: The Physical Science Basis, Contribution of the Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 2007
7. *Publicly Available Specification 2050:2008*, British Standard Institute, 2008, available on < http://www.bsigroup.com>
8. Ashby M., *Materials and the environment: eco – informed material choice*, 1st ed.; Butterworth-Heinemann Ltd, Elsevier, USA, 2009.
9. *Programma Generale di Prevenzione e Gestione – Relazione Generale Consuntiva 2009*, CONAI, 2009. Available on <http://www.conai.org/>
10. *Rapporto Rifiuti Urbani*, Istituto Superiore per la protezione e la ricerca ambientale (ISPRA), CSR , 2009. Available on < http://www.apat.gov.it>
11. Lerma, B., De Giorgi, C., Allione, C., *Design e materiali. Sensorialità sostenibilità progetto*, 1st ed.; Franco Angeli, Milano, Italy 2011.
12. Germak C. by, Design per un nuovo umanesimo. In *Uomo al centro del progetto*, 1st ed; Umberto Allemandi Editore, Torino, Italy 2008.
13. Bucchetti V. Ciravegna E., *Durabilità e scadenza nella comunicazione di prodotto*, 1st ed; Edizioni Dativo, Milano, Italy 2007.
14. Piergiovanni L., Limbo S., *Food packaging: materiali, tecnologie e qualità degli alimenti;* 1st ed; Springer, Milano, Italy, 2010.
15. European Commission - Joint Research Centre - Institute for Environment and Sustainability, *International Reference Life Cycle Data System (ILCD) Handbook*, 1st ed; Publications Office of the European Union. Luxembourg.; 2010.
16. Kano, N., N. Seraku, F. Takahashi, and S. Tsjui.. Attractive quality and must-be quality. *Hinshitsu 14* **1984**, 2, 147-56.
17. Bistagnino L., *The out side shell seen from the inside*, 1st ed; Casa Editrice Ambrosiana, Italy, 2008.
18. Allione C., De Giorgi C., Lerma B., Petruccelli L. (2012) From ecodesign guidelines to materials guidelines for a sustainable product. Qualitative and quantitative multicriteria environmental profile of a material. *Energy*, **2012**, 39,. 90-99.