Sustainable food packaging: a case study of chocolate products

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Abstract The paper deals with a multidisciplinary research, with the purpose to develop a sustainability index able to take in account the environmental, social and good quality aspects of agri-food products along their life cycle. In this multidisciplinary research the Industrial Design Research Unit of the DIPRADI Department is involved in developing an assessment method for the food packaging. Specifically the research has been started from an analysis of the state of the art of the packaging concerning three specific agri-food products, which are representative of the traditional agri-food production chain of the Piedmont Region: chocolate and sweet products, alcoholic beverage, meats and cold cuts. By the analysis of the scenario of these case studies, a multicriteria evaluation system useful for the assessment of eco-compatibility level of food packaging is under development. The results collected so far into this research, are illustrated in this paper.

1 Introduction

The paper originates from a multidisciplinary research project POLIEDRO (Pollenzo Index Environmental and Economics, research in progress, funded by the Piedmont region) aimed at developing an evaluation system for agri-food products, capable of summarising the principle of good, clean and fair and therefore capable of considering to the same level, the environmental, social and quality variables that influence the performance of the agri-food product throughout its entire life cycle. An evaluation system that on the one side is adopted by local producers to assess the level of sustainability of their products

and on the other is a guide for the consumer in the choice of agri-food products more sustainable.
Within this project, the Research Unit of Industrial Design of DIPRADI is involved, with the aim of outlining a methodology for assessing the level of sustainability of food packaging which must be integrated into Pollenzo Index.
In order to be considered sustainable, food packaging must be evaluated while taking into consideration the functional, environmental and communication requirements that it must satisfy throughout its life cycle. Environmental requirements that refer to the consumption of resources and energy and the generation of waste and emissions into the environment. Functional requirements that refer to the need to use packaging correctly, and finally communicative requirements that recall the need to recognise and identify the content, while paying particular attention to the sensory and cognitive perception offered by the various packaging.
Based on this objective, the research starts with the analysis of three case studies: chocolate, alcoholic beverages, meat, representative of the principal agri-food chains in the Piedmont region, in order to identify the evaluation criteria on which the assessment method of the packaging is based [1].

2 State of the art of food packaging

Before explaining the specific chocolate case study, the subject of this paper, the research has analysed the main criticism relating to the food packaging world, often identified in the need to increase the recyclability potential of the constituent materials, which quickly turn into waste, due to the short duration of the life cycle of the packaging itself.
This criticism is addressed in the EU Directives 94/62/EC - 2004/12/EE and has led to the creation of national consortia for the management of packaging wastes, but have not yet yielded the expected results. At European level, in fact, while on one hand the percentages of recycling of packaging materials are increasing, underlining the efficiency of consortia dedicated to this purpose, conversely, the continuous increase of per capita production of packaging waste highlights how good prevention practices are not yet consolidated [2].
Eco-design strategies aimed at improving the environmental footprint and LCA analyses that highlight the principal environmental problems of food packaging have already been studied by other researches, but rarely these studies have been focused on the existing relationships between the chain of food production and packaging and on a multi-criteria environmental evaluation of packaging

performances, which is based on qualitative and quantitative criteria [3]. Consequently, adopting a life cycle approach, the research started by comparing the relationships between the life cycle of the agri-food product and the packaging (Fig.1) which show, firstly , how the packaging itself becomes an ingredient of the food during the food production phase, and secondary only some life cycle phases can be directly controlled by the agri-food producers.

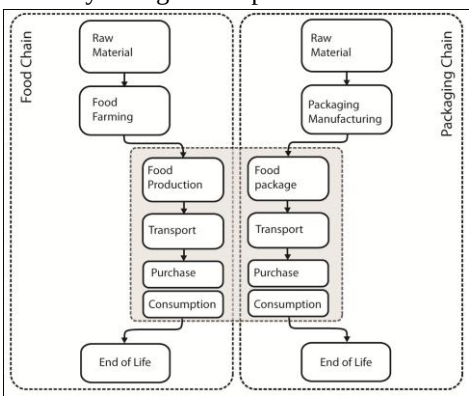

Fig. 1: Agri-food and packaging chains: life-cycle comparison

3 The Chocolate case study

On this assumptions the chocolate case study was the first experimentation field, under which they have identified the requirements-evaluation criteria on which to set the evaluation index of the packaging. In other words, the chocolate case study has been the basis on which to outline the meta-project of a first evaluation system of the packaging, to be then adopted subject to appropriate modifications and adjustments to other agri-food products.

To this end, the study started with the scenario analysis of different types of packaging currently used for the chocolate product and available on the market such as chocolates, chocolate bars and creams. It is important to underline that the classification was not made on the basis of the composition of matter or form of packaging because this approach would lead to a focus on the packaging only and not on the combination of food and packaging.

Fig. 2: Requirements investigated and Venchi sample table

Subsequently, a sample of 25 chocolate samples pertaining to three different classifications was identified, which does not aim to be representative of the actual market situation, but was selected according to the logic of highlighting the different types of possible packaging within the same category. In addition, the selection of the representative sample was made by comparing the products from a local medium-sized production plant, Venchi chocolate (which made itself available as a case study within the Poliedro project) with other products easily available on the market. Each product included in the sample was then investigated on the basis of a common form of analysis structured on a series of functional, environmental and communicative prerequisites (Fig.2). For the identification of requirements/evaluation criteria on the one hand, in the case of quantitative criteria, reference was made to SLCA (Streamlined Life Cycle Assessment) type analysis, a methodology widespread used for the analyses of packaging and on the other hand, for the qualitative criteria the demand/requirements/performances approach extended to the whole life-cycle was adopted; a design approach, conceived at the Industrial Design Degree Course [13], where man, or rather the end-user, is at the centre of the project.

From the processing of the data collected, it was thus possible to outline a reference scenario allowing any type of packaging to be included in an evaluation in order to determine its position with respect to the current market situation.

From the scenario analysis carried out based on three different types analysed it was possible to deduce some preliminary considerations about the complexity of the packaging analysed and their material composition.

First of all, in relation to the complexity of the packaging, which is valued on the basis of the number of components that constitute it (Fig.3), it is possible to argue that the packaging with the largest quantity of components is by far chocolates with about 4 components for each package, followed by creams with about 3 components, and finally the bars, the category with the largest number of samples analysed, registering an average of 1-2 components.

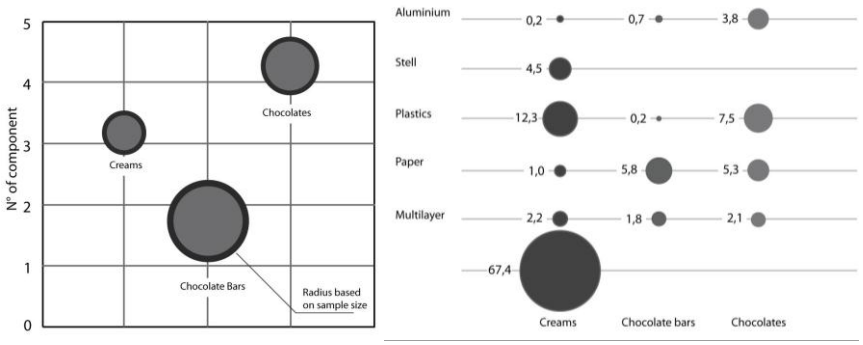

Fig. 3: Packaging complexity and material composition of packaging for 100 g of chocolate.

In relation to composition and the related masses of material involved, by analysing the averaged masses of the samples per 100 grams of packaged product, you can see that the creams, compared with a wide diversity of materials used, are reported to have a high usage of glass, as this category consists mainly of glass jars. While the chocolates contribute important values of mass that are used mainly in plastic materials and paper, all are at a lower intensity of material with a high contribution of paper material (Fig.3).
From these first assessments, it is possible to note how the three identified categories differ from each other not only based on content but also according to the different material composition of the various packaging.

4 Definition of the evaluation system

Based on this scenario analysis, the research carried on with the delineation of an assessment system, subdivided into two main sections. The first SLCA approach with the quantitative evaluation of impact indicators, the second following a qualitative functional approach.

4.1 SLCA evaluations

The SLCA type analysis was carried out by using two main quantitative indicators of environmental impact, namely:
GWP (Global Warming Potential): is an indicator that evaluates the emission of all gases that contribute to the greenhouse effect attributable to the various processing activities involved in getting the material ready for use. This indicator, also known as the Carbon Footprint is expressed in kilograms of CO2 equivalent. The most important detail used here is to calculate the only fossil component according to the PAS 2050 guidelines [5].
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 accordance with the methodology of energy analysis, the mass balance is generally calculated by adding up the different ratio of energy that are involved, i.e. direct energy, indirect energy, feedstock energy and transport energy.
The use of such indicators, currently used in streamlining analyses, is mainly due to the capacity of describing the potential impacts they have on the two environmental sectors which, at the time, are considered of major interest both from an environmental point of view as a whole (because they are attributable to global warming and the consumption of energy resources) and for their easy communicability to an audience of non-experts.
For the calculation of these SLCA indicators, a specific reference database was prepared by using as sources the data from both databases such as the Cambridge EcoSelector (Granta Design Limited) and the studies carried out by professional associations of the European producers of the principal materials primarily used in packaging (including Plastics Europe for polymeric materials, the EAA, European Aluminium Association - for aluminium, etc.). The analytical approach adopted for the environmental assessment of materials in packaging production was based on an allocation of impacts depending on the quantities of material or semi-finished product used [6] while primary data from the manufacturer are not taken into account.
Furthermore, the use of SLCA indicators referred to the Cradle to Gate phase only which, for packaging materials, is easily describable using data from literature[4], while for the definition of the end-of-life phase (Cradle to Grave), only the potential for recycling was carried out by the definition of the potential recycling rate from the official data of CONAI relating to the Italian context of packaging waste management [8].

In this way the degree of recyclability of each analysed packaging was evaluated on the basis of the actual recyclability of each component determined by the specific characteristics. For example, in the case of multilayer packaging, because of the inseparability of the different materials, or because of possible contamination with the product, they were classified as non-recyclable.
Based on this observation, an average end-of-life scenario was prepared for the non-recyclable mono-material components, obtained by allocating the recycling potential to the two remaining scenarios. For the specific case of multilayers, the average scenario of the Italian average Municipal Solid Waste (MSW) was used 2009 ISPRA figure [9] which provides that approximately 10.9% of the MSW produced is sent for incineration with the remainder used for other scenarios, and for the specific nature of multilayer that may be approximated with as landfill.
In summary, together with the SLCA indicators, a further quantitative indicator relating to the recycling potential elaborated in a specific Italian context and the quantitative evaluation given by the ratio between the weight or mass of packaging used and the amount of product contained was also undertaken, to highlight the volume of material used.

4.2 Qualitative evaluations

On the other hand, the qualitative assessments, are derived from the adoption of the demand/requirements/performances approach extended to life cycle, which allowed the identification of the functional, environmental and communicative requirements that must be satisfied by packaging. These requirements once used as reading criteria in the cataloguing of the various products covered by the analysed sample were then converted into evaluation criteria. Easily recognisable and assessable criteria through direct observation of the package, the assessment of which was based on dichotomous value scales (yes/ no), based on the fulfilment or non-fulfilment of the investigated requirement.
Some of these criteria are directly linked to the known performance that packaging must generally meet; others have been specifically designed for the packaging of chocolate.
The qualitative criteria investigated are as follows:

1) Functional criteria: in this group are collected criteria that evaluate the performance of the packaging during use of the product, such as: *Stacking capacity*: the packaging ability to be stacked due to the formal characteristics and mechanical resistance.. *Resealability*: the packaging ability to be open and close several time; *Reusability*: The packaging ability to be reused several time for other purpose.

2) Environmental Criteria: this group involves the performance criteria related to the life cycle or to the end-of-life, such as : *Separability of the components*: the possibility to separate all the material in order to assign them to correct waste treatment. *Presence of the constituent materials marking*: following the Directive 94/62/EC, or by symbols or labels for their correct disposal.
3) Communication criteria: in this group are included criteria that assess the communicative capacity of the packaging in relation to the contents, for example: *Origin of cocoa*: criterion developed to assess the willingness of companies to openly communicate the quality and sustainability of the chocolate product. *Nutritional value*: criterion used to assess the willingness to communicate information in relation to nutrition.. *Preservation method*: criterion used to highlight the possibility of communicating to the customer the correct management of the product also, through the proper use of the packaging itself.

For each of the criteria considered a score based on the satisfaction or otherwise of the specific requirement in question was allocated.

5 Definition of reference scenarios

From calculations carried out, the different categories show values, averaged on the sample, very different from each other. For example, the packaging for chocolates registers higher Carbon Footprint values compared to the other two categories, a value in contrast with the quantities of used material (Fig.4), which shows the creams category as the one with the greatest mass use of packaging with an equal amount of content. This observation refutes the common idea that lighter packaging necessarily leads to environmental benefits.

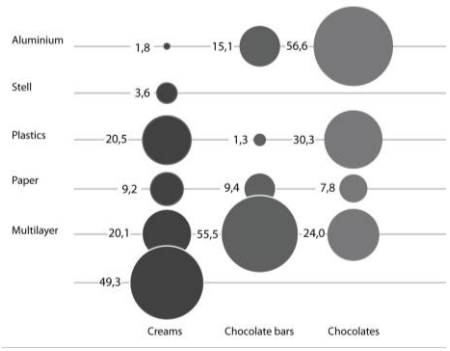

Fig. 4: Carbon Footprint for 100 g of chocolate [data in gCO_2eq]

However, the interest of the study is not to highlight the differences between the categories but to show how, within the same category, it is possible to find different result ranges that describe the current scenario of chocolate packaging in order to develop an evaluation model, to be used for the assessment of packaging relating to the three categories defined.
From calculations carried out both by quantitative and qualitative assessments in fig 6, average values for each indicator within each category were extrapolated. Starting with the average value, the upper and lower average values of the sample were shown. Using the maximum and minimum points recorded as further reference, the division of the variable of the results in 5 representative ranges was obtained, that is:

- average values: values included between the upper and lower average of the samples analysed
- values above average: values included between the upper average and the maximum value analysed
- values below average: values included between the lower average and the minimum value analysed
- values lower than the minimum analysed
- values higher than the maximum analysed.

Thanks to the elaboration of the ranges it is possible, by carrying out an analysis of a chocolate packaging with the same procedures described in the paper, to transform an evaluation of the quantitative indices into value judgments so as to relate them to the quality indicators previously analysed.

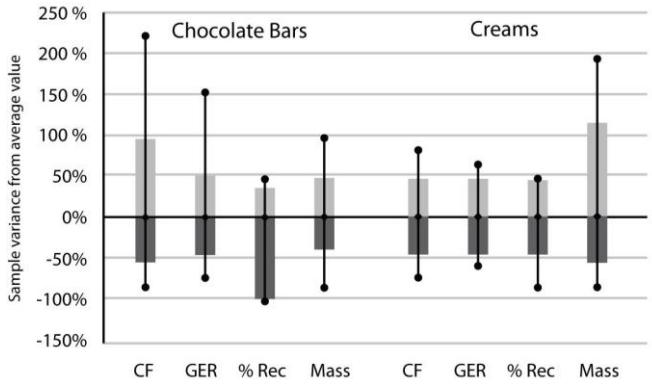

Fig. 5: Variance of sample from average value

Wanting to transform the judgement on all indicators into a single yardstick, the last step in the definition of the evaluation system is the creation of weighting systems for the various indices. This final part of the work is still considered to be

in the development stage. Further studies in this direction are in progress using non-verbal and Eye-tracking machine analytical methodologies.

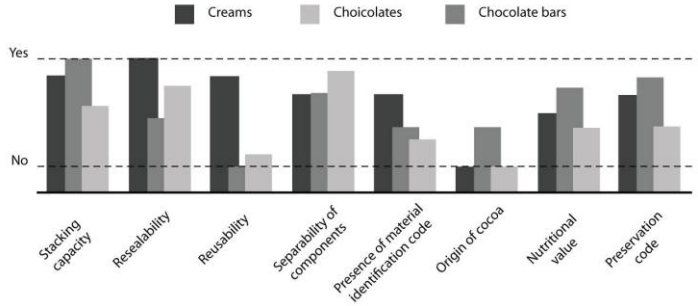

Fig. 6: qualitative investigated requirements product sample

Eye-tracking allows us to analyse how the subjects behave in an unaware way during the observation of a stimulus, without controlling the look and attention: it is based on the recording, obtained by means of sensors, of the reflection of a beam of infrared rays projected onto the pupil. This methodology, applied to the design, allows important information to be extracted for the designer who wants to transmit easily identifiable communicative values to his project [10].
The use of this tool, supported by appropriate evaluations of the results, therefore allows the understanding of how the consumer may perceive the product-packaging, "measured" started with the performance prerequisites previously defined, also taking into account aspects associated with its expressiveness and the ways in which it is perceived, while reading in a synesthetic way its functionality, communication, end-of-life management, sustainability and sensory perception.

6 Sensory perception of food packaging

The packaging of the food product is a key element and may be considered as an ingredient in all respects. The packaging, particularly that of food products, has multiple roles: to contain, protect and maintain unaltered the "taste" quality of the food product, communicate its goodness, serve as a vehicle of information, "anticipate" the content, win over the purchaser and be sustainable. In addition, the packaging is the first contact we have with the product that we intend or are considering to purchase: shape, colour, graphics and materials are very important elements for a successful marketing campaign and have a key role in the commercial success of a product. The packaging sector, of food and not just food, is the place of considerable advancements from a functional and expressive point

of view, by varying the classic impact that it has on itself and the products contained. In particular, the experimentations/innovations related to materials are increasingly more widespread.
The materials used in packaging today are smart carriers of information to the consumer: recent packaging can release substances that kill microbes, change colour to indicate preservation problems, contain microchips to make known the origin of the product and verify its traceability. But not only: packaging in edible material, that can be eaten, transforming the packaging into a consumable product, starch-based food films, polysaccharides or vegetable oils, to replace the films used routinely; materials that enhance the visual characteristics of the packaging, materials that exalt tactile qualities: pigments for effect, luminescent paints, surface treatments that create soft-touch effects ... The materials and the most innovative technologies also allow the packaging to have smell and sound qualities that anticipate their content, packets of potato crisps that make a "crock", scented packaging that make the moment of purchasing a true sensory experience.
In its ongoing process of innovation in materials research the theme of the perception of the materials themselves has become central, the expressive–sensory properties of which, sought-after and exalted, acquire increasing importance: increasingly the procedures according to which man perceives the subject and evaluates their experience are taken more and more into consideration [9].
The materials, and the packaging which they form, can and should therefore be evaluated just like the food and beverages that contain, by interpreting the sensations perceived by the senses. Sensory evaluation is the scientific discipline that measures, analyses and interprets these sensations and is applied in the food industry for the development of new products and the evaluation of the perceived quality: sensory analysis, through objective methods that can be used on different types of products, not only food, uses Man, with his experience and culture, as a means of measurement and evaluation.
Sensory perception and sustainability: a necessary but very difficult union. The most interesting developments in the food packaging sector, will certainly be those generated from the crossover between these two spheres, for a sensory sustainability.

7 Conclusions

The paper illustrates the results achieved to date in the definition of a multi-criteria evaluation of the packaging of chocolate products.

An evaluation system that in the next steps of research will be verified with the analysis of two successive case studies of wine and meat and with appropriate adjustments may then be used for the evaluation of the packaging of agri-food products in general.

8 References

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