Journal Pre-proof

Seafood consumers engagement in reducing environmental impacts from packaging

Cheila Almeida, Jara Laso, David Baptista de Sousa, Ronan Cooney, Paula Quinteiro, Neil Rowan, Ana Cláudia Dias, Eoghan Clifford, Rodrigo G. Reboredo, María Margallo, Maria Leonor Nunes, António Marques

PII: S0048-9697(22)07949-9

DOI: https://doi.org/10.1016/j.scitotenv.2022.160846

Reference: STOTEN 160846

To appear in: *Science of the Total Environment*

Received date: 29 July 2022

Revised date: 27 September 2022

Accepted date: 7 December 2022

Please cite this article as: C. Almeida, J. Laso, D.B. de Sousa, et al., Seafood consumers engagement in reducing environmental impacts from packaging, *Science of the Total Environment* (2022), https://doi.org/10.1016/j.scitotenv.2022.160846

Table of Contents – Manuscript structure

Title

Seafood consumers engagement in reducing environmental impacts from packaging

Author names and affiliations

Cheila Almeida[1, 2]
Jara Laso[3]
David Baptista de Sousa[4]
Ronan Cooney[5, 6]
Paula Quinteiro[7]
Neil Rowan[8]
Ana Cláudia Dias[7]
Eoghan Clifford[5, 6]
Rodrigo G. Reboredo[4]
María Margallo[3]
Maria Leonor Nunes[2]
António Marques[1, 2]

[1] Instituto Português do Mar e da Atmosfera (IPMA), Divisão de Aquacultura, Valorização e Bioprospeção, Avenida Doutor Alfredo Magalhães Ramalho 6, 1495-165 Lisboa, Portugal
[2] Centro Interdisciplinar de Investigação Marinha e Ambiental (CIIMAR), Terminal de Cruzeiros do Porto de Leixões, Avenida General Norton de Matos, S/N, 4450-208 Matosinhos, Portugal
[3] Departamento de Ingenierías Químicas y Biomolecular, Universidad de Cantabria, Avda. de Los Castros, s.n., 39005 Santander, Spain
[4] ANFACO-CECOPESCA, Campus University 16, 36310 Vigo PO, Spain
[5] School of Engineering, National University of Ireland Galway, H91 HX31, Ireland
[6] Ryan Institute, National University of Ireland Galway, H91 HX31, Ireland
[7] Centre for Environmental and Marine Studies (CESAM), Department of Environment and Planning, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
[8] Bioscience Research Institute, Technological University of the Shannon Midlands Midwest, Ireland

E-mail address, telephone and fax numbers of the corresponding author

cheila.almeida@ipma.pt

Abstract

Packaging is essential to protect food, inform consumers, and avoid food waste, yet it can also contribute to the environmental footprint of products. Recycling waste treatment potentially provides more environmental benefits than other options (e.g., landfill), but only 66% of packaging waste goes to recycling in the European Union. However, the prevention of

packaging production with greater reuse, while extending the lifetime or improving packaging design should be firstly encouraged. This highlights the need to assess the willingness of consumers in reducing the environmental impact of seafood products from packaging. An online questionnaire was conducted in three countries (Portugal, Spain, and Ireland), composed of four sections: (i) seafood consumption, (ii) waste separation to be sent recycling, (iii) willingness to purchase seafood products with packaging designed to reduce environmental impact, and (iv) sociodemographic characteristics. Findings revealed that respondents from Spain and Portugal reported a slightly higher frequency of waste sent to recycle compared to Ireland. Irish respondents appear to have more difficulties about the type of plastic materials that can be sent to recycling due to Irish waste management capabilities; whereas Spanish and Portuguese respondents were not fully aware that packaging does not need to be washed prior to recycling. The most popular alternatives to improve the sustainability of seafood packaging were the use of reusable packaging, compostable packaging material, glass jars for canned seafood instead of cans, and intelligent packaging. Most respondents were willing to pay more for seafood products that use more sustainable packaging (62% for Spain, 68% for Ireland, 70% for Portugal) and half of the respondents intimated that they avoid seafood products due to excessive packaging. With more detailed information on the waste management of packaging, seafood consumers could actively contribute with their attitudes where commensurate changes can improve environmental assessment of seafood.

Keywords

Packaging; fish; survey; recycling; plastic; consumer behaviour

1. Introduction

While the primary function of packaging is to protect the product, less attention has been paid to packaging functions that reduce food waste. Such measures on packaging ability to reduce waste can be more important than the type of packaging material (Wikström et al., 2014; Williams & Wikström, 2011). Packaging effectively decreases the environmental burden of the product when considering the food loss related to injury during transportation or the environmental burden of additional production to compensate for the food loss (Sasaki et al., 2021). To fully assess the environmental impacts of food packaging, the trade-off between investment in packaging and potential reduced food waste should be quantified (Molina-Besch et al., 2019). The end-of-life treatment option will compromise the contribution of the packaging to the total environmental assessment of the product. For example, packaging materials can be recycled into new products, produce energy if incinerated, or, in the worst-case scenario, end up in landfill (Wikström et al., 2019).

The current recycling rate of overall packaging waste in the European Union (EU) is around 66% (European Environment Agency, 2021). In a production-based approach, the responsibility for packaging waste management is on the countries and producers, encouraging them to improve the recyclability of their packaging materials (Gao et al., 2022). However, for many years EU countries have shipped their plastic waste to other countries to meet their recycling targets, until 2017, when China refused to take any new waste (Brooks et al., 2018). This constraint reinforced the motivation to domestically recycle plastic waste and introduce more returnable or refillable containers in food packaging.

The transition towards a low-carbon footprint and circular economy, by extending the useful life of materials and encouraging recycling whilst reducing resource use, has become a priority in the EU (Tallentire & Steubing, 2020). The packaging sector is one of the major contributors to waste generation. In the EU, about 80 million tonnes of packaging waste was generated in

2019 (Eurostat, 2022). Paper and cardboard represented the main waste materials contributing 41% of the total packaging waste generated, while plastic and glass represented both 19%, wood 16%, and metal 5% (Eurostat, 2022). The Packaging Waste Directive contains updated measures to prevent the production of packaging waste, and promote its reuse, recycling, and other forms of recovery instead of final disposal (European Commission, 2018). It established the following recycling targets for each packaging material to be achieved by 2030: 85% for paper/cardboard; 80% for metal; 75% for glass; 60% for aluminium, 55% for plastic; and 30% for wood. These recycling targets should be calculated with the weight at the point where packaging waste enters the recycling operation (European Commission, 2018). Such targets are linked to the Circular Economy Action Plan which aims to make all packaging fully recyclable by 2030 (European Commission, 2020). In this sense, EU countries are required to adopt appropriate measures such as enhancing the circularity of waste systems, reduce the complexity of packaging, set up a minimum percentage of reusable packaging, design for bio-based materials application and re-use, and define deposit-return schemes. All these measures should be aligned with national programmes and economic instruments as incentives (e.g., taxes, subsidies, and charges) to achieve the established targets.

Studies on the environmental impacts of food production have shown that later stages in the supply system, such as packaging, retail, and transport combined contribute less than 14% of greenhouse gas (GHG) emissions (Poore & Nemecek, 2018). However, in the case of specific types of products such as bottled drinks or canning products, packaging can contribute significantly to a product's GHG emissions since the production of glass and metal requires a high level of energy (Poovarodom et al., 2012). Hence, packaging can contribute within a large range of values to the environmental burden of seafood products. The carbon footprint (CF) of packaging goes from almost zero up to 19 kg CO_2 eq per kg of seafood, corresponding to less than 1% to 89% of the total CF of seafood products, differing substantially depending on the

type of material used and its processing (Almeida et al. 2021). For example, the best case scenario is freezing lobster in a waxed cardboard box (van Putten et al., 2016) and the worst case is canned mussels in tinplate (Iribarren et al., 2010).

Most seafood studies focused on the production stage, whereas few have considered the complexity of seafood processing considering the supply chain from an integrated perspective. Packaging can have different levels, including primary packaging that is in direct contact with the product (e.g., aluminium can), secondary packaging corresponding to subsequent layers of material that contain one or more primary packaging (e.g., cardboard box), or tertiary packaging for transport, handling, and distribution (e.g., pallets) (ISO, 2016). The resources used along the seafood supply chain require consistent management to reduce waste and improve efficiency (Liu et al., 2020). However, seafood is highly prone to spoilage compared to other food (Love et al., 2015). As an example, canning allows for the preservation of perishable products such as small pelagic fish (e.g., sardines), caught in large volumes, thus increasing the proportion of fish available for human consumption (Almeida et al., 2015). Viewed through recycling commitments, aluminium cans perform relatively well due to the 81%[1] recycling rate for aluminium in the EU. However, plastic appears more favourable than aluminium if we prioritize climate impact since aluminium production relies on a more carbon-intensive production processes and is difficult to offset even with higher overall recycling rates. Therefore, given that frozen, chilled or cooked seafood packaging consists mainly of paper, plastic and wood, on average it contributes to less than 5% of the CF, corresponding to less than 1 kg CO_2 eq per kg of seafood (Almeida et al., 2021). Plastics could also present an advantage in food distribution if their reuse is considered, being the most environmentally friendly option when compared to single-use cardboard boxes (Abejón et al., 2020). Expanded polystyrene (EPS) packaging represents one of the most widely used materials in seafood, due

[1] https://international-aluminium.org/resource/aluminium-recycling-fact-sheet/

to its resistance to temperature changes during transport or storage and a significant environmental impact reduction is obtained when EPS is recycled and/or reused (Konstantinidis et al., 2021).

Plastic packaging waste has the lowest recycling rate compared with other materials such as glass, paper, and metals (Gao et al., 2022). Only 9% of plastic waste is recycled worldwide, with the overwhelming majority of global plastic waste being landfilled or ending up contaminating the environment (Geyer et al., 2017). Plastic recycling represents a challenge due to the wide variety of additives and blends used in a multitude of products and the variation of material properties (e.g., shortening of the polymer chains) that limit the number of times products can be recycled (Geyer et al., 2017). A quality drop in the plastic recycled material reduces its application options, typically leading to down-cycling and delaying final disposal, but not avoiding it (van der Harst et al., 2016).

Measures to reduce the environmental impact of packaging, for example, switching from single-use to multi-use packaging (e.g., reusing a glass jar after the main product has been consumed) would further cut the carbon footprint, while also reducing waste. Reusable packaging systems are more often found in business-to-business markets for transport (e.g., boxes, pallets) while in business-to-consumer system addresses refillable-by-bulk-dispenser or parent packaging (e.g., refill packaging made with less material than parent packaging), and returnable packaging (Coelho et al., 2020). Other measures can be applied to reduce the environmental footprint of packaging such as the removal of excessive packaging, redesigning packaging to use less material, and plain packaging so that it can be easily recycled (Gao et al., 2022). Nevertheless, a shared responsibility approach is needed with incentives for producers and suppliers but also a consumer responsibility when the environmental impact of products includes consumption and end-of-life. As an example, consumers can pay a tax for the

management of waste they generate, irrespective of where the packaging was produced, to guarantee that end-of-life of packaging waste follows the best interest of all (Gao et al., 2022). Household waste sorting is an essential aspect of the waste management system; moreover, correct sorting of food packaging waste is cost-effective since it facilitates recycling and enhances the quality of the recycled materials (Nemat et al., 2019). However, environmental studies with data arising specifically on consumer behaviour from pre-purchase to post-consumption are scarce. There has been limited investigation into the relationship between sustainable packaging and consumer purchasing behaviour, and more studies should be conducted to cover the different products and consumer perspectives (Martinho et al., 2015). The seafood industry is considered to be less innovative in new packaging development compared to other adjacent industries such as meat and poultry (Olsen et al., 2017). Furthermore, seafood packaging attributes appear to be underappreciated by researchers (Carlucci et al., 2015). Most of the research related to seafood consumption focus on consumers' preferences, motives and barriers (e.g., Cardoso et al., 2016; Pieniak et al., 2007; Verbeke et al., 2005). Attributes such as taste, appearance, freshness, and health benefits are often valued over production-related features (e.g., sustainability, production method) (Witter et al., 2021). Consumers value, above all, packaging attributes associated with quality, including the possibility to visualize the product (Olsen et al., 2017). To our knowledge, no research has been performed yet on the willingness of consumers in reducing the environmental impact of seafood products from packaging and if they proceed correctly at home when dealing with different seafood packaging waste materials. To collect survey data, consumer studies can be developed using web-based questionnaires (e.g., Altintzoglou, Einarsdottir, et al., 2010; Minnens et al., 2020), consumer panels (Altintzoglou, Verbeke, et al., 2010; Kole et al., 2009) or recruitment companies (Altintzoglou et al., 2021). In this study, an online survey was developed to approach consumers in three countries, Spain (ES), Portugal

(PT), and Ireland (IE). These countries were selected because they are European Atlantic countries, and the NEPTUNUS project, the framework where this research was developed, had data available.

The main goals of this study were to establish among consumers from the three countries: 1) the reported rate of household waste sent to recycling for different seafood packaging types and associated materials; 2) if a relationship exists between seafood consumption frequency and the rate of seafood packaging separation for recycling; 3) knowledge regarding the recycling practices of different types of seafood packaging or materials; and 4) the willingness of consumers to purchase seafood products that use packaging with lower environmental impacts.

2. Material and methods

The data collection was carried out online and it was preferred over other sampling methods, such as face-to-face questionnaires, based on convenience. Respondents can connect to the internet using various types of mobile devices and it allows instant access to a wide audience, irrespective of their geographical location, which makes it appropriate for cross-sectional studies and/or international comparisons (Evans & Mathur, 2018; Ilieva et al., 2002). A web-based questionnaire is easily accessible by a broader range of consumers and has the advantage to facilitate data entry, and overcoming time and budget constraints (Rogers, 2007). The anonymity possible by the internet is believed to help respondents in sharing their experiences and opinions (Van Selm & Jankowski, 2006). This sampling method has also disadvantages since only respondents with access to computer technology and the internet will be able to participate and the answering instructions could be unclear (Callegaro et al., 2014). There is also a problem with sampling bias in non-probability panels (i.e., when people select themselves into the panel) with the impossibility to know in advance the probability of

respondents' characteristics (Evans & Mathur, 2018). When results of online surveys cannot be defined as representative of the population, non-probability samples can be valuable as they may be representative of a subgroup of the total population (Van Selm & Jankowski, 2006). Therefore, it was a suitable sampling method for the explorative aim of the analysis. The survey questions were prepared in English, tested in an online form, and translated into other three languages: Portuguese, Spanish, and Gaelic. Adaptations were made in the different versions to better represent the specificities of each country (e.g., the recycling bin where plastic and metal should be discarded in Portugal and Spain is "yellow" and in Ireland is not associated exactly with a colour).

Data were collected through an online survey created on the LimeSurvey online tool. The links of four surveys were released corresponding to each language and shared via social media (e.g., Twitter, Facebook, LinkedIn) and email, with 640 validated and complete responses obtained: 228 from Portugal (PT), 234 from Spain (ES), and 154 from Ireland (IE). Additionally, seven answers were received from other countries and 17 more that did not present socio-economic data were eliminated. For those who agreed to participate, written informed consent was given at the beginning of the survey according to the General Data Protection Regulation (GDPR). Data collection was conducted from July to September 2021.

The questionnaire was structured in three parts (supplementary material): the first part collected information on seafood consumption patterns; the second section included questions about recycling and willingness to accept seafood products with packaging improvements to reduce environmental impacts; and the last section collected data on individuals' sociodemographic characteristics, such as gender, age, level of education completed, occupation, number of household members, living with children, living distance from the coast, and type of living place (e.g., rural versus city and inland versus coastal). Questions on seafood consumption habits referred explicitly to the period before the COVID-

19 pandemic. Also, it was clarified in the consumption group of questions that "seafood" was meant as "fisheries and aquaculture products including fish, crustaceans and molluscs" and seafood consumption frequency should relate to an average weight per meal of a "portion of around 150 g or about the size and thickness of your hand".

Data were analysed by country; for the seafood consumption frequency, a cluster diagram was prepared to represent the respondents with high consumption which corresponded to more than twice a week, and low consumption which corresponded to equal or less than twice a week. Statistical differences were verified for socio-economic characteristics, seafood consumption frequencies, and the reported rate of household waste sent to recycling for different seafood packaging types with Pearson's chi-squared test for contingency tables. For tests of associations between gender and answers related to seafood consumption and packaging, we used Chi-squared, Spearman's correlation, Kruskal-Wallis, Two-sided Student's t-test, and Wilcoxon signed-rank tests.

3. Results

3.1. Seafood consumption frequency of the respondents

Regarding the seafood consumption frequency (**Figure 1**), most of the respondents reported consuming seafood between one to three times a week (ES – 68.8%, PT – 57.0%, IE – 61.0%). However, significant differences were found between participating countries ($p < 10^{-10}$, Chi-squared test), which can be explained by a much higher percentage of Spanish and Portuguese who consumed seafood four to seven times a week (ES – 17.5%, PT – 27.6%) compared to Irish consumers (IE - 3.2%), and a much higher percentage of Irish people who answered that they never consumed seafood (IE – 4.5%). When analysing the frequency of seafood consumption in and outside the home (**Figure 2**), similarities between Portugal and Spain were observed. For consumption at home, a higher percentage of respondents ate one to three times a week

in both countries when compared to Ireland (ES - 72.6%, PT - 61.4%, IE - 58.8%). For consumption of seafood outside the home, more respondents from Ireland eat seafood only once a month or less than compared to Portugal or Spain (ES - 53.0%, PT - 48.7%, IE - 72.1%).

When the analysis of the consumption frequency was by type of seafood product (**Figure 3**), there was a higher consumption of fresh/chilled products in the three countries, with a higher number of respondents answering that they consumed these products one to three times a week (ES – 60.3%, PT – 54.8%, IE – 41.6%). For frozen and canned seafood, the highest number of respondents occurred from Spain and Portugal who answered that they consumed these products one to three times a week (ES – 35.9%, 49.1%; PT – 35.9%, 34.2%, respectively). However, it was once or less a month for Irish respondents (IE – 45.5%, 41.6%). Seafood products that were marketed as pre-cooked or ready-to-eat were less consumed in the three countries since the majority of respondents never consumed these products (ES – 58.1%, PT – 47.4%, IE – 46.8%). Smoked products were consumed in general by most of the respondents from the three countries once or less a month (ES – 48.3%, PT – 55.7%, IE – 57.8%) while dried and salted products were also eaten in Portugal once or less a month (PT – 48.2%); but, in the case of Spain and Ireland most people never eat such products (ES - 43.6%, IE – 76.0%).

3.2. Household waste sent to recycling and knowledge of recycling guidelines

In the case of Spain and Portugal, the largest number of respondents answered that they "always" send their non-organic waste (i.e., glass, paper, plastic waste) to specific bins to collect waste for recycling (**Figure 4**), as reflected by 40.6% and 42.3% response rates respectively. In the case of respondents from Ireland, the largest number answered that they separate non-organic waste "often" (75% of the time) to send it to recycling, corresponding to

29.5% of the respondents. When the question was specific to seafood packaging types, in the case of Spain and Portugal the largest number of respondents answered that they "always" sent metal cans, and plastic package including expanded polystyrene, paper package, and glass jars to recycling. In the case of Ireland, a different pattern was observed where the largest number of Irish respondents answered that they "always" sent metal cans, paper packaging, and glass jars to recycling. However, for plastic packaging, the majority answered "often" and expanded polystyrene was "almost never" sent to recycling (**Table I**).

When the respondents were divided into groups according to their seafood consumption frequency, a statistically significant difference related to the behaviour of sending household waste to recycling was found ($p < 0.006$, Chi-squared test). Respondents who self-reported higher consumption of seafood also self-reported higher intention of sending non-organic waste for recycling (**Table II**).

By quantifying correct answers to the statements (**Table III**) (question number 10 in the questionnaire available in the supplementary material), it was possible to characterize in part the knowledge of recycling practices when consumers deal with different types of packaging or materials. The answer that provided the greatest agreement by the three participating countries related to the statement that "metal cans from canned seafood packaging should be put in the yellow waste container or recycling bin" (TRUE was the correct answer in all cases). It received the highest number of correct answers from the three countries and significant differences were found between countries ($p = 0.02$, Chi-squared test), driven by the higher number of correct answers from PT. The answer that "empty plastic bags used for fresh seafood packaging should be put in yellow waste container to recycle or recycling bin" (TRUE

was the correct answer to ES and PT; FALSE was the correct answer to IE) received the second highest number of correct answers from the three countries and differences between countries were significative (p = 0.0028, Chi-squared test). In terms of whether it is necessary to wash metal cans from canned seafood packaging before they are sent to recycling (FALSE in the case of ES and PT, and TRUE in the case of IE), it received the lowest number of correct answers from Spain (47.9%), less than half, and highest from Ireland (76.0%). Differences between countries were significant (p = 0.00000008, Chi-squared test), driven by a higher correct number of answers from IE and lower from ES. The statement saying that "it is not necessary to wash plastic packaging from frozen seafood products before they are sent to waste" (TRUE was the correct answer in all cases) got overall the lowest number of correct answers and differences between countries were significant (p = 10^{-13}, Chi-squared test). Ireland is the country that overall had a lower average (63.9%) when compared to Spain (68.1%) and Portugal (78.5%).

3.3. Willing to consume seafood products that use more sustainable packaging or avoid products with excess packaging

The most accepted alternatives for more sustainable seafood packaging according to responses from the three countries were (i) reusable packaging (e.g., return glass jar from canned seafood to the producer/retailer), (ii) a compostable type of packaging material (e.g., flexible film made from crustacean shells), (iii) "glass jar packaging for canning seafood instead of metal cans, and (iv) intelligent packaging (which extends shelf-life and maintains the quality of the food) (**Table IV**) (question number 11 in the questionnaire available in the supplementary material). Between 81.6% and 96.5% of the respondents answered that they are receptive to these practices. Only 37.0% to 59.1% of the respondents were willing to use a

squeeze-tube type packaging instead of metal cans and plastic pouch packaging for canning seafood instead of metal cans, which demonstrates that these should be considered less successful measures to improve seafood packaging from the consumers' point of view.

The avoidance of seafood products due to excess packaging (e.g., a package that has a secondary layer of carton) was confirmed by around half of the respondents, with Portuguese respondents having the highest rate (56.6%) and Irish the lowest with 44.8% of the respondents (**Table V**). The dried and/or salted products (e.g., salted and dried cod) were considered to have the least excessive packaging for a post-harvest processed seafood product (ES - 5.1%, PT - 4.8%, IE - 3.2%). The opposite trend was found for pre-cooked/ready-to-eat type of products, whereby significant numbers considered packaging excessive (ES - 37.2%, PT - 39.5%, IE - 30.5%).

The majority of respondents, between 62.0% for Spain, 68.8% for Ireland, and 70.2% for Portugal are willing to pay more for seafood products that use more sustainable packaging (**Table VI**). Of these respondents, the largest number answered that would be willing to pay 10% more (ES - 43.6%, PT - 53.1%, IE - 46.1%).

3.4. Socio-economic characteristics

The socio-economic characteristics of the sample (**Table VII**) were statistically different between countries for all characteristics except gender. The percentage of female respondents was slightly greater in the three countries (between 64.5% to 67.1%). The sample from Spain

presented a younger population (more in 21-40 years old), fewer people lived with parents (25.2%), a greater percentage of households without children (46.2%), and more people that lived in a small town (51.7%) compared to the other two countries. The majority of respondents from Portugal were between 41 to 60 years old (64.9%) and, compared to the other two countries, had a higher level of education (30.7% of respondents had a PhD), the majority lived in less than 50 km distance from the coast (93.9%) and in a large town (60.5%) and also did not live with parents (89.9%). The Irish sample had the highest percentage of people with three or more children (13.6%), the highest household size comprising five to six members (16.2 and 5.2% respectively), and the highest proportion of respondents that lived rurally (40.3%). Despite being an island, 46.1% of the Irish respondents lived further than 50 km from the sea, as opposed to 6.1% of Portuguese and 16.7% of Spanish respondents.

When the results from the questions were tested against the socio-demographic characteristics of the samples (**Table VII**), it was possible to find some statistical differences. Older respondents (Rho = 0.17, p = 0.00001, Spearman's correlation test), not living with parents (p = 0.0045, Kruskal-Wallis test), and living on the seaside reported a significantly higher seafood consumption frequency (p = 0.000001, Kruskal-Wallis test). A higher frequency of seafood consumption at home was reported by older respondents (*Rho* = 0.19, p = 0.0000014, Spearman's correlation test), not living with parents (p = 0.03, Kruskal-Wallis test), but living with children (Rho = 0.11, p = 0.007, Spearman's correlation test), and living on the seaside (p = 0.000001, Kruskal-Wallis test).

Males appear to have a significantly higher frequency of seafood consumption outside the home (p = 0.0005, Chi-squared test). This trend seems essentially driven by Portugal, the only sample for which the difference is significant (p = 0.002, Chi-squared test). Age follows the

same pattern which might be explained by the fact that older people have usually better jobs and a higher economic level (Rho = 0.15, p = 0.0002, Spearman's correlation test). Students and the unemployed have lower seafood consumption outside the home (p = 0.002, Kruskal-Wallis test) which is normal due to budget limitations, together with respondents with a higher number of people living at the household (Rho = -0.098; p = 0.02 Spearman's correlation test). Respondents not living with parents (p = 0.00002, Kruskal-Wallis test) and living in cities presented higher seafood consumption outside the home (p = 0.005, Kruskal-Wallis test).

Females appear to have a higher willingness to reuse packaging (86.5%) than males (81.3%) (p = 0.02, Chi-squared test). There is also a slight tendency that respondents from larger households are not willing to use reusable packaging (p = 0.01, Wilcoxon signed-rank test). The older respondents are more willing to use a compostable type of packaging (p = 0.001, Two-sided Student's t-test), the result is mostly explained by the differences found among the Spanish cohort where those that responded positively were on average 11 years older than those who responded no (p = 0.006, Two-sided Student's t-test). On the contrary, respondents that are students (p = 0.0003, Chi squared test), living in larger households (p = 0.046, Wilcoxon signed-rank test), living with parents (p = 0.0000002, Chi squared test), or have a higher number of children in the household (p = 0.02, Wilcoxon signed-rank test) answered that they are not willing to use a compostable type of packaging, and again the result is mostly explained by the differences found among the Spanish cohort. Finally, it was found that there is a slight trend for more educated people to accept the use of a squeeze-tube type packaging instead of metal cans (p = 0.004, Wilcoxon signed-rank test).

4. Discussion

Addressing consumer concerns by way of understanding behavioural aspects and preferences is important as this can also inform changes towards sustainable practices and promote innovation through social marketing (Domegan, 2021; Rowan & Pogue, 2021). The present study focused on the role of consumers across Portugal, Spain and Ireland in terms of understanding practices towards waste of seafood packaging that can affect environmental sustainability. Results revealed that seafood consumption frequency is relatively similar between Spain and Portugal, with the majority of respondents reporting the consumption of these products between one to three times a week, with a slightly higher frequency occurring for the Portuguese cohort. Ireland showed a different pattern where there was a general lower frequency of seafood consumption, including a small percentage of respondents (4.5%) that never ate seafood. This result is not surprising as apparent per capita consumption of fishery and aquaculture products is highest in Portugal and Spain, with 59.9 kg and 46.0 kg per year respectively, and slightly above the EU average (24.0 kg) in the case of Ireland with 25.5 kg (EUMOFA, 2021). Data obtained for Portugal in previous studies provided a seafood consumption of four to five times a week, which is extremely high (Almeida et al., 2015; Cardoso et al., 2013). Furthermore, Spanish citizens were associated with regular fish consumers, with 46% of respondents saying that they consumed fish more than once a week, while Ireland was at 18% (Zander & Feucht, 2018).

Regarding the different processing products, there is a higher consumption in the three countries for fresh/chilled seafood products. Frozen and canned seafood has the highest consumption frequency in Spain and Portugal, with the largest number of respondents answering one to three times a week for both types of products; but, in Ireland it was one or fewer times a month. Pre-cooked or ready-to-eat seafood was the least consumed in the three countries with the largest number of respondents never eating these products. Respondents

that reported higher seafood consumption related to responses with higher rates of household separation of non-organic waste to recycling. This could be of relevance since most of the seafood consumption occurs at home (one to three times a week had the majority of answers from the three countries: 72.6% in ES, 61.4% in PT, 57.8% in IE) and the seafood packaging waste could thus be significant in this setting. Furthermore, since a higher frequency of seafood consumption at home was reported by older respondents, not living with parents, but living with children, and living on the seaside.

Respondents appear to be aligned with recycling behaviour as the largest number of respondents from Spain and Portugal said they separate all household waste to be sent to recycling whereas Ireland sends almost all. Differences in responses were noted when the question posed was specific to the type of packaging materials. There were lower rates of waste separation to recycling for Ireland for plastic waste, especially with packaging made by EPS. The reason behind these results could be related to the lack of information provided to consumers on how to deal with different waste materials or a lack of waste management capacity. Providing recycling information is particularly important to enhance consumer knowledge of the value of packaging and to eliminate uncertainty about sorting different packaging materials (Nemat et al., 2019). From open questions, it was possible to understand that some respondents seem to be confused about what type of plastics can be recycled. Since many types of plastic exist and only a few cannot be recycled, a more efficient message could be to request consumers to separate all plastic to be sent to recycling and, in this way, avoid the risk of losing plastics from packaging that would go to undifferentiated waste treatment, for example, landfilling. Furthermore, in Ireland non-rigid plastic (e.g., plastic film, grocery bags) could only be sent to recycling waste bins since September 2021, which might explain the plastic recycling responses in Ireland to some extent were contrary to Spain and Portugal.

When we analysed the four statements relating to knowledge about recycling including where metal cans, plastic packaging from frozen, EPS boxes, and plastic bags from fresh seafood should be put or not in the recycling bin, on average, Ireland received the lowest percentage of correct answers to these statements (63.9%) compared to Spain (68.1%) and Portugal (78.5%). The fact that in Ireland plastic packaging, metals, and all paper and cardboard materials should be sent to the same recycling bin (whereas in Spain and Portugal there is a yellow container for plastic and metal packaging and a blue container for paper and cardboard) can have a counter-productive effect on an individual's capacity to send packaging to recycling. There is also another difference between countries as in Ireland, in contrast to Portugal and Spain, consumers are asked to wash packaging before sending them to the recycling bin. This happens because in Ireland, since recycling materials are mixed, dirty or unsuitable items could contaminate the entire contents. This behaviour seems to be evident among Irish consumers since Irish participants reported a higher percentage of correct answers compared to the other two countries when asked if it is necessary to wash metal cans from canned seafood packaging before they are discarded (76.6% for IE against 47.9% for ES and 64.5% for PT). One reason that might explain these results is that metal cans might be perceived as dirtier packaging compared to plastic due to the associated oil used to preserve canned seafood. It seems that a higher effort exists in Ireland in communicating this specific behaviour of washing dirty packaging when it is needed. In Spain and Portugal, this seems to be confusing since results for washing metal had the lowest number of correct answers from all the statements in both countries' samples. Washing packaging does not add any benefit to the recycling process since grease, traces of food, or even liquid residues do not interfere with the process, as there is a washing phase in the recycling treatment that eliminates these traces. This means that, when washing the packages at home before sending them to the recycling bin, consumers in

Portugal and Spain are doubling the work and wasting water. The other three statements related to washing plastic packaging from frozen seafood, EPS boxes, and plastic bags from fresh seafood all got a higher level of correct answers from respondents from Portugal, with 72.4%, 70.6% and 68.9%, and lower from Spain (57.7%, 61.5%, and 63.7% respectively) and Ireland (32.5%, 58.4%, and 64.3% respectively). The results suggest that improved communication using more appropriate guiding and policy information could help consumers in Spain and Portugal adjust their behaviour. This is supported by observations made by Klaiman et al., (2017) on the testing of plastic or boxboard sandwich containers, where having to clean packaging can alter preferences for packaging material, but this practice did affect consumer recycling behaviour at the household.

The statement that had the highest consensus and highest number of correct answers, with 90.4% on average, from the three countries, was if metal cans from canned seafood should be put in the recycling bin. This result is in accordance with the high level of aluminium recycling rate in Europe, which in Spain and Portugal, it can also be recovered from undifferentiated waste. Nevertheless, it demonstrates that more effort should be done for other types of packaging materials such as plastics. In general, it seems that there is a lack of information about plastic packaging recycling since some respondents intimated in open answers that they do not fully know the guidelines and believe that seafood plastic packaging cannot be sent to the recycling bin and, for example, that EPS package cannot be recycled. Also, some respondents believe that they need to wash the plastic and EPS to be recycled and, since they do not want to do it, they avoid contaminating “clean” packaging in the recycling of packages (in the case of Spain and Portugal). To overcome these misunderstandings, it would be important to communicate detailed procedures applicable to each type of material, including the different types of plastics (e.g., EPS, High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE)), and also explain the destination of these types of materials after

recycling. Specific communication for certain types of seafood products could also support the willingness of consumers to send more household waste to recycling, especially in Spain and Portugal, where seafood consumption at home is so frequent. Nevertheless, the different recycling guidelines implemented in the EU countries could impair the consistency of recycling behaviours in households at the European level.

The most consensual alternatives to using more sustainable packaging for seafood from the three countries were the use of reusable packaging (e.g., return glass jars from canning seafood to the producer/retailer), glass jar packaging for canning seafood instead of metal cans, compostable types of packaging material (e.g., flexible film made from crustacean shells), and intelligent packaging (which extends shelf-life and maintains the quality of the food). By reusing packaging, a significant reduction in the environmental impact of packaging could be feasibly achieved as a second use will allocate part of the environmental cost of the packaging. Therefore, this alternative could be promoted in case companies find it feasible (e.g. implement a return deposit scheme on glass jars for some beverage products such as water bottles). The main barrier identified by producers is a major logistical complexity, which requires the reorganisation of supply chains to ensure that packaging is available and returned through distribution and that consumers maintain their loyalty (Coelho et al., 2020). Another possibility could be the use of reusable containers from consumers when purchasing seafood at the fishmongers to avoid the use of plastic bags/heat-sealed bags. Females appear to have a higher willingness to reuse packaging than males, but not respondents from larger households that may be due to an idea that this possibility could imply extra work for the household routine which might be already complicated in households with more people.

Glass jar packaging for canning seafood could represent environmental benefits when compared to aluminium (Laso et al., 2017). In the same way, through packages with intelligent

packaging consumers may also reduce seafood waste and prevent unnecessary transport and logistics from an early stage (Cammarelle et al., 2021; Salgado et al., 2021). The use of a compostable type of packaging material could improve the end-of-life of seafood packaging, which is mainly an alternative to plastic; but, it raises the point as to how many waste compost treatments are municipalities prepared to do and if what is an appropriate disposal alternative. Older respondents seem to be more willing to use a compostable type of packaging, and on the contrary, respondents that are students, living in larger households, living with parents, or having a higher number of children in the household answered that they are not so willing to use compostable packaging. These results are mostly explained by the differences found among the Spanish cohort which is characterized also by younger respondents when compared with the other two samples, meaning older people could be more aware of the possibilities of composting their waste.

New design features that make packaging more sustainable could also increase the likelihood that sustainable packaging is chosen which could potentially increase the level of positive-environmental behaviour of consumers (Martinho et al., 2015). However, the use of a "squeeze-tube type packaging instead of metal cans" as is commonly marketed in northern European countries and "plastic pouch packaging for canning seafood instead of metal cans" had around half or less than half of the answers so these should be considered less successful measures to improve seafood packaging from the consumers' point of view. These options imply a redesign of the packaging which may make the package less recognizable to consumers or less convenient, and the use of different types of material may reduce the appeal and attractiveness (Prendergast & Pitt, 1996). Even though, a slight trend was found for more educated people to accept the use of a squeeze-tube type packaging instead of metal cans.

Respondents appear to be concerned with packaging because around half of them intimated that they avoid seafood products due to excessive packaging (e.g., packaging that has a secondary layer of carton). This is especially the case for pre-cooked/ready-to-eat types of products since it was the type of post-harvest processed product that had a higher number of respondents who considered it to have excessive packaging. These products are less consumed in the three participating countries since the majority of respondents answered that they never eat them. The second level of products that respondents associate with excessive packaging is frozen products. In contrast, dried and/or salted products (e.g., *bacalhau* or mackerel) were the seafood products that fewer respondents from the three countries considered had excessive packaging. The majority of respondents from Portugal answered that they consumed dried and salted seafood products once or fewer times a month; but, in the case of Spain and Ireland the highest number of respondents never tried them. Fresh or chilled seafood products, the most common way of consuming seafood in these countries, were also not considered as having excessive packaging, especially by respondents from Spain and Portugal.

The majority of respondents were willing to pay more for seafood products that use more sustainable packaging (for example a 10% increase in price was acceptable for 62.0% of respondents in Spain, 68.8% in Ireland 70.2% in Portugal). This result shows the commitment of consumers in contributing to an effort that may need to be carried out in partnership with industries, presenting opportunities for innovation and more environmentally-friendly solutions (Steenson & Creedon, 2022). This result is aligned with consumer motivation to pay for more sustainable seafood products which is positively correlated to respondents' income and their environmental concerns, with a maximum premium of 10% of the product price that consumers were happy to pay (Salladarré et al., 2016). Nevertheless, many people find

difficulties in defining terms such as 'sustainability' in relation to something as specific as packaging and the principles in improving environmental impacts need to be translated into more clear requirements (Lewis, 2005).

Overall, the results highlight a positive attitude of consumers towards recycling and care for packaging with lower environmental impact. However, the results could also be biased by the highly-educated cohort sample which may affect the consumers' knowledge as well as their reported attitudes. This also highlights an area to improve upon for future research to reach consumers from a broader socio-demographic range and consequently obtain a more holistic perspective of environmental concerns. Other limitations of this present research should be noted. Firstly, the sample is not representative of countries' populations and results should be discussed as representing only the group of people, with their respective socio-demographic characteristics, that answered the survey. Additional research is recommended to ensure a full characterisation of the entire seafood consumer market in European countries. A second limitation is related to the data collection method adopted as the survey was processed online, representing a strong barrier for people with low motivations and/or unfamiliar with new technologies or social networks and as a result, higher educated people were more likely to answer to the survey (e.g., Cammarelle et al., 2021). Nevertheless, results can give an outlook on how much respondents are willing to contribute to reducing the environmental impact of seafood products through packaging and start a discussion on what is needed to improve the end-of-life of seafood packaging. A third issue that one should bear in mind is that answers with self-declared intentions related to more responsible behaviours or willingness to pay can be overestimated by people responding too positively when compared to reality.

Food packaging and its attributes can potentially hinder or motivate consumers to sort packaging waste correctly. The design of packaging influences recycling behaviour and, therefore, the recyclability of packaging should be considered an inherent value of the packaging, similar to other attributes such as beauty or durability (Nemat et al., 2019). Addressing consumer behavioural and attitude changes towards seafood packaging is important. In this instance the transition towards increased circularity where communication can be done by deploying appropriate marketing practices to educate and empower consumers (Domegan, 2021; Rowan & Casey, 2021). Consumers are only one of the key players in the seafood value chain and efforts are also needed from other groups of stakeholders (e.g., policymakers, dieticians, consumer organisations, retailers, fishermen, seafood processing industry) to ensure that future seafood production, processing, distribution and consumption become more sustainable. In this sense, transparent and trustful information with the help of certification labelling that incorporates different information related to seafood is recommended (Sacchettini et al., 2021). As an example, labelling based on Product Environmental Footprint (PEF) guide could be developed, delivering information to consumers about products within food categories and integrating topics that are still poorly described, such as the end-of-life of packaging materials (Hélias et al., 2022).

5. Conclusions

The reported rates of household waste sent to recycling of different seafood packaging types and associated materials were relatively high in the three countries analysed: Spain, Portugal, and Ireland. Respondents also appear to be willing to pay more for seafood products that use more sustainable packaging and avoid seafood products with excess packaging. A general relationship was observed between seafood consumption frequency, which mainly occurs at home, and seafood packaging separation for recycling. These results need to be linked with a

sample of respondents that in general is characterised by highly-educated people and mostly employed. However, these findings can provide insights as to where to invest resources to inform on sustaining behaviour in seafood packaging waste disposal. Recycling practices at the household level could be improved upon with more appropriate information provided about specific types of seafood packaging and materials, especially for plastics that present a huge diversity of types. This may be significantly important in countries where there is high seafood consumption, especially at home, as is the case for Spain and Portugal. An increase in the quantity of packaging sent to recycling and efficiency of the waste management system can hence improve the circularity and reduce the environmental cost of seafood related to packaging and its materials.

6. Acknowledgements

We are most grateful to Filipe Ferreira from IPMA Informatic Systems Division for help in preparing the online survey using LimeSurvey software and Nuno Barbosa Morais from iMM for help with data analysis. The authors would like to acknowledge the promotion of the survey by the various agencies, stakeholders and groups. This work was supported by the NEPTUNUS project (EAPA 57c/2018). The authors would like to acknowledge the financial support of Interreg Atlantic Area. Ana Cláudia Dias and Paula Quinteiro acknowledge FCT/MCTES for the financial support to CESAM (UIDB/50017/2020+UIDP/50017/2020+LA/P/0094/2020), through national funds, and to the research contracts CEECIND/02174/2017 and CEECIND/00143/2017, respectively.

7. References

Abejón, R., Bala, A., Vázquez-Rowe, I., Aldaco, R., & Fullana-i-Palmer, P. (2020). When plastic packaging should be preferred: Life cycle analysis of packages for fruit and vegetable

distribution in the Spanish peninsular market. *Resources, Conservation and Recycling*, *155*(November 2019), 104666. https://doi.org/10.1016/j.resconrec.2019.104666

Almeida, C., Altintzoglou, T., Cabral, H., & Vaz, S. (2015). Does seafood knowledge relate to more sustainable consumption? *British Food Journal*, *117*(2), 894–914. https://doi.org/10.1108/BFJ-04-2014-0156

Almeida, C., Loubet, P., da Costa, T. P., Quinteiro, P., Laso, J., Baptista de Sousa, D., Cooney, R., Mellett, S., Sonnemann, G., Rodríguez, C. J., Rowan, N., Clifford, E., Ruiz-Salmón, I., Margallo, M., Aldaco, R., Nunes, M. L., Dias, A. C., & Marques, A. (2021). Packaging environmental impact on seafood supply chains: A review of life cycle assessment studies. *Journal of Industrial Ecology*, 1–18. https://doi.org/10.1111/jiec.13189

Almeida, C., Vaz, S., & Ziegler, F. (2015). Environmental Life Cycle Assessment of a Canned Sardine Product from Portugal. *Journal of Industrial Ecology*, *19*(4), 607–617. https://doi.org/10.1111/jiec.12219

Altintzoglou, T., Einarsdottir, G., Valsdottir, T., Schelvis, R., Skåra, T., & Luten, J. (2010). A voice-of-consumer approach in development of new seafood product concepts. *Journal of Aquatic Food Product Technology*, *19*(2), 130–145. https://doi.org/10.1080/10498850.2010.493636

Altintzoglou, T., Honkanen, P., & Whitaker, R. D. (2021). Influence of the involvement in food waste reduction on attitudes towards sustainable products containing seafood by-products. *Journal of Cleaner Production*, *285*. https://doi.org/10.1016/j.jclepro.2020.125487

Altintzoglou, T., Verbeke, W., Vanhonacker, F., & Luten, J. (2010). The image of fish from aquaculture among Europeans: Impact of exposure to balanced information. *Journal of Aquatic Food Product Technology*, *19*(2), 103–119. https://doi.org/10.1080/10498850.2010.492093

Brooks, A. L., Wang, S., & Jambeck, J. R. (2018). The Chinese import ban and its impact on global plastic waste trade. *Science Advances*, *4*(6), 1–8. https://doi.org/10.1126/sciadv.aat0131

Callegaro, M., Baker, R., Bethlehem, J., Göritz, A. S., Krosnick, J. A., & Lavrakas, P. J. (2014). Online panel research: History, concepts, applications and a look at the future. *Online Panel Research: A Data Quality Perspective*, *2012*, 1–22. https://doi.org/10.1002/9781118763520.ch1

Cammarelle, A., Viscecchia, R., & Bimbo, F. (2021). Intention to purchase active and intelligent packaging to reduce household food waste: Evidence from italian consumers. *Sustainability (Switzerland)*, *13*(8). https://doi.org/10.3390/su13084486

Cardoso, C., Lourenço, H., Costa, S., Gonçalves, S., & Leonor Nunes, M. (2016). Survey Into the Seafood Consumption Preferences and Patterns in the Portuguese Population: Education, Age, and Health Variability. *Journal of Food Products Marketing*, *22*(4), 421–435. https://doi.org/10.1080/10454446.2014.949982

Cardoso, C., Lourenço, H., Costa, S., Gonçalves, S., & Nunes, M. L. (2013). Survey into the seafood consumption preferences and patterns in the portuguese population. Gender and regional variability. *Appetite*, *64*, 20–31. https://doi.org/10.1016/j.appet.2012.12.022

Carlucci, D., Nocella, G., De Devitiis, B., Viscecchia, R., Bimbo, F., & Nardone, G. (2015). Consumer purchasing behaviour towards fish and seafood products. Patterns and insights from a sample of international studies. *Appetite*, *84*, 212–227. https://doi.org/10.1016/j.appet.2014.10.008

Coelho, P. M., Corona, B., ten Klooster, R., & Worrell, E. (2020). Sustainability of reusable packaging–Current situation and trends. *Resources, Conservation & Recycling: X*, *6*(November 2019), 100037. https://doi.org/10.1016/j.rcrx.2020.100037

Domegan, C. (2021). Social marketing and behavioural change in a systems setting. *Current*

Opinion in Environmental Science & Health, *23*, 100275. https://doi.org/10.1016/j.coesh.2021.100275

EUMOFA. (2021). The EU Fish Market - 2021 Edition. In *European Market Observatory for Fisheries and Aquaculture Products*. https://doi.org/10.2771/563899

European Commission. (2018). *DIRECTIVE (EU) 2018/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018, Amending directive 94/62/EC on Packaging and Packaging Waste*. http://data.europa.eu/eli/dir/2018/852/oj

European Commission. (2020). *Circular economy action plan. In European Commission (Issue March)*. http://doi.org/10.2775/855540

European Environment Agency. (2021). *Waste recycling in Europe*. https://www.eea.europa.eu/ims/waste-recycling-in-europe

Eurostat. (2022). *Packaging waste statistics*. https://ec.europa.eu/eurostat/statistics-explained

Evans, J. R., & Mathur, A. (2018). The value of online surveys: a look back and a look ahead. *Internet Research*, *28*(4), 854–887. https://doi.org/10.1108/IntR-03-2018-0089

Gao, X., Dall'erba, S., Ellison, B., Aveline, A. F. T., & Yang, C. (2022). When one cannot bypass the byproducts: Plastic packaging waste embedded in production and export. *Journal of Industrial Ecology*, 1–15. https://doi.org/10.1111/jiec.13282

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), 3–8. https://doi.org/10.1126/sciadv.1700782

Hélias, A., van der Werf, H. M. G., Soler, L.-G., Aggeri, F., Dourmad, J.-Y., Julia, C., Nabec, L., Pellerin, S., Ruffieux, B., & Trystram, G. (2022). Implementing environmental labelling of food products in France. *The International Journal of Life Cycle Assessment*, *0123456789*. https://doi.org/10.1007/s11367-022-02071-8

Ilieva, J., Baron, S., & Healey, N. M. (2002). Online surveys in marketing research: Pros and cons. *International Journal of Market Research*, *44*(3).

Iribarren, D., Hospido, A., Moreira, M. T., & Feijoo, G. (2010). Carbon footprint of canned mussels from a business-to-consumer approach. A starting point for mussel processors and policy makers. *Environmental Science and Policy*, *13*(6), 509–521. https://doi.org/10.1016/j.envsci.2010.05.003

ISO. (2016). *Packaging — Vocabulary — Part 1: General terms. ISO21067-1*. International Organization for Standardization.

Kole, A. P. W., Altintzoglou, T., Schelvis-Smit, R. A. A. M., & Luten, J. B. (2009). The effects of different types of product information on the consumer product evaluation for fresh cod in real life settings. *Food Quality and Preference*, *20*(3), 187–194. https://doi.org/10.1016/j.foodqual.2008.09.003

Konstantinidis, E., Perdikaris, C., & Ganias, K. (2021). Life cycle assessment during packaging of market-sized seabass and meagre: necessary adaptations toward GHG neutrality. *International Journal of Life Cycle Assessment*, *26*(7), 1456–1470. https://doi.org/10.1007/s11367-021-01943-9

Laso, J., Margallo, M., Fullana, P., Bala, A., Gazulla, C., Irabien, A., & Aldaco, R. (2017). Introducing life cycle thinking to define best available techniques for products: Application to the anchovy canning industry. *Journal of Cleaner Production*, *155*, 139–150. https://doi.org/10.1016/j.jclepro.2016.08.040

Lewis, H. (2005). Defining product stewardship and sustainability in the Australian packaging industry. *Environmental Science and Policy*, *8*(1), 45–55. https://doi.org/10.1016/j.envsci.2004.09.002

Liu, G., Arthur, M., Viglia, S., Xue, J., Meng, F., & Lombardi, G. V. (2020). Seafood-energy-water nexus: A study on resource use efficiency and the environmental impact of seafood consumption in China. *Journal of Cleaner Production*, *277*, 124088. https://doi.org/10.1016/j.jclepro.2020.124088

Love, D. C., Fry, J. P., Milli, M. C., & Neff, R. A. (2015). Wasted seafood in the United States: Quantifying loss from production to consumption and moving toward solutions. *Global Environmental Change*, *35*, 116–124. https://doi.org/10.1016/j.gloenvcha.2015.08.013

Martinho, G., Pires, A., Portela, G., & Fonseca, M. (2015). Factors affecting consumers' choices concerning sustainable packaging during product purchase and recycling. *Resources, Conservation and Recycling*, *103*, 58–68. https://doi.org/10.1016/j.resconrec.2015.07.012

Minnens, F., Marques, A., Domingo, J. L., & Verbeke, W. (2020). Consumers' acceptance of an online tool with personalized health risk-benefit communication about seafood consumption. *Food and Chemical Toxicology*, *144*(311820), 311820. https://doi.org/10.1016/j.fct.2020.111573

Molina-Besch, K., Wikström, F., & Williams, H. (2019). The environmental impact of packaging in food supply chains—does life cycle assessment of food provide the full picture? *International Journal of Life Cycle Assessment*, *24*(1), 37–50. https://doi.org/10.1007/s11367-018-1500-6

Nemat, B., Razzaghi, M., Bolton, K., & Rousta, K. (2019). The Role of Food Packaging Design in Consumer Recycling Behavior—A Literature Review. *Sustainability*, *11*(16), 4350. https://doi.org/10.3390/su11164350

Olsen, S. O., Tuu, H. H., & Grunert, K. G. (2017). Attribute importance segmentation of Norwegian seafood consumers: The inclusion of salient packaging attributes. *Appetite*, *117*, 214–223. https://doi.org/10.1016/j.appet.2017.06.028

Pieniak, Z., Verbeke, W., Scholderer, J., Brunsø, K., & Olsen, S. O. (2007). European consumers' use of and trust in information sources about fish. *Food Quality and Preference*, *18*(8), 1050–1063. https://doi.org/10.1016/j.foodqual.2007.05.001

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Poovarodom, N., Ponnak, C., & Manatphrom, N. (2012). Comparative Carbon Footprint of Packaging Systems for Tuna Products. *Packaging Technology and Science*, *25*(5), 249–257. https://doi.org/10.1002/pts.975

Prendergast, G., & Pitt, L. (1996). Packaging, marketing, logistics and the environment: are there trade-offs? *International Journal of Physical Distribution & Logistics Management*, *26*(6), 60–72. https://doi.org/10.1108/09600039610125206

Rogers, P. J. (2007). *Theory-Based Evaluation: Reflections Ten Years On*. *114*, 63–81. https://doi.org/10.1002/ev

Rowan, N. J., & Casey, O. (2021). Empower Eco multiactor HUB: A triple helix 'academia-industry-authority' approach to creating and sharing potentially disruptive tools for addressing novel and emerging new Green Deal opportunities under a United Nations Sustainable Development Goals fram. *Current Opinion in Environmental Science & Health*, *21*, 100254. https://doi.org/10.1016/j.coesh.2021.100254

Rowan, N. J., & Pogue, R. (2021). Editorial overview: Green new deal era — Current challenges and emerging opportunities for developing sustaining and disruptive innovation. *Current Opinion in Environmental Science & Health*, *22*, 100294. https://doi.org/10.1016/j.coesh.2021.100294

Sacchettini, G., Castellini, G., Graffigna, G., Hung, C. Y., Lambri, M., Marques, A., Perrella, F., Savarese, M., Verbeke, W., & Capri, E. (2021). Assessing consumers' attitudes, expectations and intentions towards health and sustainability regarding seafood consumption in Italy. *Science of The Total Environment*, *789*, 148049. https://doi.org/10.1016/j.scitotenv.2021.148049

Salgado, P. R., Di Giorgio, L., Musso, Y. S., & Mauri, A. N. (2021). Recent Developments in Smart Food Packaging Focused on Biobased and Biodegradable Polymers. *Frontiers in Sustainable Food Systems*, *5*(April), 1–30. https://doi.org/10.3389/fsufs.2021.630393

Salladarré, F., Brécard, D., Lucas, S., & Ollivier, P. (2016). Are French consumers ready to pay a premium for eco-labeled seafood products? A contingent valuation estimation with heterogeneous anchoring. *Agricultural Economics (United Kingdom)*, *47*(2), 247–258. https://doi.org/10.1111/agec.12226

Sasaki, Y., Orikasa, T., Nakamura, N., Hayashi, K., Yasaka, Y., Makino, N., Shobatake, K., Koide, S., & Shiina, T. (2021). Life cycle assessment of peach transportation considering trade-off between food loss and environmental impact. *International Journal of Life Cycle Assessment*, *26*(4), 822–837. https://doi.org/10.1007/s11367-020-01832-7

Steenson, S., & Creedon, A. (2022). *Plenty more fish in the sea : is there a place for seafood within a healthier and more sustainable diet ? February*, 261–273. https://doi.org/10.1111/nbu.12553

Tallentire, C. W., & Steubing, B. (2020). The environmental benefits of improving packaging waste collection in Europe. *Waste Management*, *103*, 426–436. https://doi.org/10.1016/j.wasman.2019.12.045

van der Harst, E., Potting, J., & Kroeze, C. (2016). Comparison of different methods to include recycling in LCAs of aluminium cans and disposable polystyrene cups. *Waste Management*, *48*, 565–583. https://doi.org/10.1016/j.wasman.2015.09.027

van Putten, I. E., Farmery, A. K., Green, B. S., Hobday, A. J., Lim-Camacho, L., Norman-López, A., & Parker, R. W. (2016). The Environmental Impact of Two Australian Rock Lobster Fishery Supply Chains under a Changing Climate. *Journal of Industrial Ecology*, *20*(6), 1384–1398. https://doi.org/10.1111/jiec.12382

Van Selm, M., & Jankowski, N. W. (2006). Conducting online surveys. *Quality and Quantity*, *40*(3), 435–456. https://doi.org/10.1007/s11135-005-8081-8

Verbeke, W., Sioen, I., Pieniak, Z., Van Camp, J., & De Henauw, S. (2005). Consumer perception versus scientific evidence about health benefits and safety risks from fish consumption.

Public Health Nutrition, *8*(4), 422–429. https://doi.org/10.1079/phn2004697

Wikström, F., Verghese, K., Auras, R., Olsson, A., Williams, H., Wever, R., Grönman, K., Kvalvåg Pettersen, M., Møller, H., & Soukka, R. (2019). Packaging Strategies That Save Food: A Research Agenda for 2030. *Journal of Industrial Ecology*, *23*(3), 532–540. https://doi.org/10.1111/jiec.12769

Wikström, F., Williams, H., Verghese, K., & Clune, S. (2014). The influence of packaging attributes on consumer behaviour in food-packaging life cycle assessment studies - A neglected topic. *Journal of Cleaner Production*, *73*, 100–108. https://doi.org/10.1016/j.jclepro.2013.10.042

Williams, H., & Wikström, F. (2011). Environmental impact of packaging and food losses in a life cycle perspective: A comparative analysis of five food items. *Journal of Cleaner Production*, *19*(1), 43–48. https://doi.org/10.1016/j.jclepro.2010.08.008

Witter, A., Murray, G., & Sumaila, U. R. (2021). Consumer seafood preferences related to alternative food networks and their value chains. *Marine Policy*, *131*(February). https://doi.org/10.1016/j.marpol.2021.104694

Zander, K., & Feucht, Y. (2018). Consumers' Willingness to Pay for Sustainable Seafood Made in Europe. *Journal of International Food and Agribusiness Marketing*, *30*(3), 251–275. https://doi.org/10.1080/08974438.2017.1413611

Table I. Percentage of respondents that perform separation of the different seafood packaging types/materials to be sent to recycling in the three countries (%).

		Spain (n=234)	Portugal (n=228)	Ireland (n=154)
Metal cans	Never (0%)	12.0	4.4	9.7
	Almost never (25%)	8.1	8.3	5.2
	Sometimes (50%)	9.0	6.6	6.5
	Often (75%)	14.1	11.0	11.0
	Always (100%)	56.8	69.7	67.5
Plastic package	Never (0%)	7.3	3.1	7.1
	Almost never (25%)	6.8	4.8	10.4
	Sometimes (50%)	8.1	9.6	16.9
	Often (75%)	21.8	22.4	37.0
	Always (100%)	56.0	60.1	28.6
Paper package	Never (0%)	8.5	7.0	9.1
	Almost never (25%)	12.4	9.2	9.7
	Sometimes (50%)	11.1	12.3	7.8
	Often (75%)	20.9	20.6	16.2
	Always (100%)	47.0	50.9	57.1
Glass jar	Never (0%)	9.4	4.8	13.0
	Almost never (25%)	6.8	5.3	1.3
	Sometimes (50%)	9.0	6.6	1.3
	Often (75%)	13.7	9.6	9.1
	Always (100%)	61.1	73.7	75.3
Expanded polystyrene	Never (0%)	19.2	16.2	44.2
	Almost never (25%)	12.4	10.5	14.9
	Sometimes (50%)	14.5	8.8	13.6

Often (75%)	19.2	11.8	9.7
Always (100%)	34.6	52.6	17.5

Table II. Percentage of respondents that separate household packaging waste to recycling associated with their level of seafood consumption (%).

	Rate of household waste sent to recycling				
	0 %	**25 %**	**50 %**	**75 %**	**100 %**
High consumption (> 2x week)	1.3	7.7	11.1	34.2	45.7
Low consumption (≤ 2x week)	3.3	10.1	10.7	38.0	31.9

Table III. Percentage of respondents from each country that gave the correct answer about recycling guidelines statements (%).

Countries version / Statement [correct answers]	**Spain (ES) (n=234)**	**Portugal (PT) (n=228)**	**Ireland (PT) (n=154)**
ES, PT / Metal cans from canned seafood packaging should be put in yellow waste container to recycle [TRUE] – IE / Metal cans from canned seafood packaging should be put in the recycling bin [TRUE] *	88.0	94.7	87.7
ES, PT / It is necessary to wash metal cans from canned seafood packaging before they are sent to waste [FALSE] - IE / It is not necessary to wash metal cans from canned seafood packaging before they are sent to waste [FALSE] *	47.9	64.5	76.0
ES, PT / The plastic packaging from frozen seafood products should be put in normal/undifferentiated waste container [FALSE] - IE / The plastic packaging from frozen seafood products	77.8	93.0	46.8

should be put in the general waste [FALSE] *			
ES, PT, IE / It is not necessary to wash plastic packaging from frozen seafood products before they are sent to waste [TRUE] *	57.7	72.4	32.5
ES, PT / Expanded polystyrene boxes used for fresh seafood should be put in yellow waste container to recycle [TRUE] - IE / Expanded polystyrene boxes used for fresh seafood should be put in the recycling bin [FALSE]	70.5	75.4	73.4
ES, PT, IE / It is necessary to wash expanded polystyrene boxes before they are sent to waste [FALSE] *	61.1	70.6	58.4
ES, PT / If empty, plastic bags used for fresh seafood packaging should be put in yellow waste container to recycle [TRUE] - IE / If empty, plastic bags used for fresh seafood packaging should be put in the recycling bin [FALSE] *	77.8	88.2	72.1
ES, PT / It is not necessary to wash plastic bags used for fresh seafood packaging before they are sent to waste [TRUE] - IE / It is not necessary to wash plastic bags used for fresh seafood packaging before they are sent to waste [FALSE]	63.7	68.9	64.3
Average	68.1	78.5	63.9

** Statistically significant ($p < 0.05$, Chi-Squared test) differences were found between countries.*

Table IV. Percentage of respondents from each country that answered "yes" about their willingness to use the seafood packaging alternatives (%).

Seafood packaging alternative	**Spain (n=234)**	**Portugal (n=228)**	**Ireland (n=154)**
Reuse packaging (e.g., return glass jar from canning seafood to the producer/retailer)	81.6	88.6	88.3

Use a compostable type of packaging material (e.g., flexible film made from crustacean shells) *	90.2	96.5	94.8
Use a squeeze tube type packaging instead of metal cans	44.0	48.7	37.0
Use plastic pouch packaging for canning seafood instead of metal cans	54.7	52.2	59.1
Use glass jar packaging for canning seafood instead of metal cans	93.2	95.6	90.9
Use of intelligent packaging (which extends shelf-life and maintain the quality of the food)	90.6	92.1	90.9

** Statistically significant ($p < 0.05$, Chi-Squared test) differences were found between countries.*

Table V. Percentage of respondents from each country that avoid seafood products with excess packaging and consider that post-harvest processing products have excess packaging (%).

		Spain (n=234)	**Portugal (n=228)**	**Ireland (n=154)**
Avoid seafood products with excess packaging		49.1	56.6	44.8
Type of post-harvesting processing products	Fresh / Chilled	7.3	12.3	23.4
	Frozen	18.8	33.8	18.2
	Canned	15.0	23.2	4.5
	Pre-cooked / Ready-to-eat	37.2	39.5	30.5
	Smoked	12.0	20.2	13.6
	Dried and/or salted	5.1	4.8	3.2

Table VI. Percentage of respondents from each country that are willing to pay more for seafood products that use more sustainable packaging (e.g., package that allows to send all the packaging materials to recycling) and how much more (%).

	Spain (n=234)	**Portugal (n=228)**	**Ireland (n=154)**
Pay more for seafood products that use more	62.0	70.2	68.8

sustainable packaging				
How much more	*10 %*	43.6	53.1	46.1
	25 %	14.1	14.9	18.2
	50 %	3.4	0.4	2.6
	> 50 %	0.9	1.8	1.9

Table VII. Summary statistics of the socio-economic characteristics of the samples (%).

		Spain sample	**Portugal sample**	**Ireland sample**
Gender	Female	64.5	67.1	66.2
	Male	34.2	32.5	29.9
	Other	0.0	0.0	1.3
	Prefer not to say	1.3	0.4	2.6
Age (years) *	≤ 20	14.1	0.0	0.0
	21-40	41.9	25.0	44.2
	41-60	38.9	64.9	46.1
	≥ 61	4.7	10.1	9.7
Education level *	Primary or below	2.1	0.0	0.0
	Lower secondary	13.7	0.9	0.6
	Higher secondary	3.4	6.1	5.2
	Additional technical training	11.1	1.8	8.4
	BSc (or similar)	23.5	27.6	30.5
	MSc (or similar)	32.5	32.9	36.4
	Bellow upper education			
	Tertiary education	-	-	-
	PhD (or similar)	13.7	30.7	18.2
Current occupation *	Student	16.7	7.9	16.2

	Employed	72.6	79.4	68.2
	Self employed	3.4	6.6	4.5
	Unemployed	4.3	2.2	2.6
	Responsible for the household	0.9	1.8	2.6
	Retired	2.1	2.2	5.8
Number of people living in the household *	1	9.4	12.3	9.1
	2	25.2	28.5	32.5
	3	31.2	27.6	16.9
	4	27.8	25.0	19.5
	5	4.3	5.3	16.2
	≥ 6	1.7	0.9	5.2
Live with parents *	No	74.8	89.9	81.8
	Yes	25.2	10.1	18.2
Number of children in the household *	0	46.2	55.7	56.5
	1	25.6	21.1	14.9
	2	23.9	18.4	14.9
	≥ 3	3.8	4.8	13.6
Type of living area *	Large town	21.8	60.5	37.7
	Rural area or village	26.5	13.6	40.3
	Small or middle-sized town	51.7	25.9	22.1
Living distance from the sea *	Inland (more than 50 km from the coast)	16.7	6.1	46.1
	On the seaside (less than 50 km from the coast)	83.3	93.9	53.9

** Statistically significant ($p < 0.05$, Chi-Squared test) differences were found between countries.*

*Table VIII. Statistical test results (*p *values) between socio-demographic variables and answers related with seafood consumption and packaging. * Statistically significant ($p < 0.05$) differences were found; and the following statistical test was used: [1] Chi-squared test; [2] Spearman's correlation test; [3] Kruskal-Wallis test; [4] Two-sided Student's t-test, [5] Wilcoxon signed-rank test.*

	Gender	**Age**	**Education level**	**Occupation**	**Nº people in the household**	**Live with parents**	**Nº children in the household**	**Type of living area**	**Living distance from the sea**
Seafood consumption frequency	- [1]	Rho = 0.17; *p* = 0.00001 [2] *	- [2]	- [3]	- [2]	0.0045 * [3]	- [2]	- [3]	0.000001 * [3]
Seafood consumption at home	- [1]	Rho = 0.19; *p* = 0.0000014 [2] *	- [2]	- [3]	- [2]	0.029 * [3]	Rho = 0.11; *p* = 0.007 * [2]	- [3]	0.00002 * [3]
Seafood consumption outside the home	0.0005 * [1]	Rho = 0.15; *p* = 0.00018 [2] *	- [2]	0.0017 * [3]	Rho = -0.098; *p* = 0.017 * [2]	0.00002 * [3]	- [2]	0.0047 * [3]	0.0076 * [3]
Willingness to reuse packaging	0.021 * [1]	- [4]	- [5]	- [1]	0.046 [5]	- [1]	- [5]	- [1]	- [1]
Willingness to use a compostable type of packaging material	- [1]	0.001 * [4]	- [5]	0.0003 [1]	0.01 [5]	0.0000002 [1]	0.02 [5]	- [1]	- [1]
Willingness	- [1]	- [4]	0.004 * [5]	- [1]	- [5]	- [1]	- [5]	- [1]	- [1]

to use a squeeze tube type packaging instead of metal cans									
Willingness to use plastic pouch packaging for canned seafood	- [1]	- [4]	- [5]	- [1]	- [5]	- [1]	- [5]	- [1]	- [1]
Willingness to use glass jar packaging for canned seafood	- [1]	- [4]	- [5]	- [1]	[5]	- [1]	- [5]	- [1]	- [1]
Willingness to use of intelligent packaging	- [1]	- [4]	- [5]	- [1]	- [5]	- [1]	- [5]	- [1]	- [1]
Avoid seafood products with excess packaging	- [1]	- [4]	- [5]	- [1]	- [5]	- [1]	- [5]	- [1]	- [1]
Pay more for seafood	- [1]	- [4]	- [5]	- [1]	- [5]	- [1]	- [5]	- [1]	- [1]

products that use more sustainable packaging									

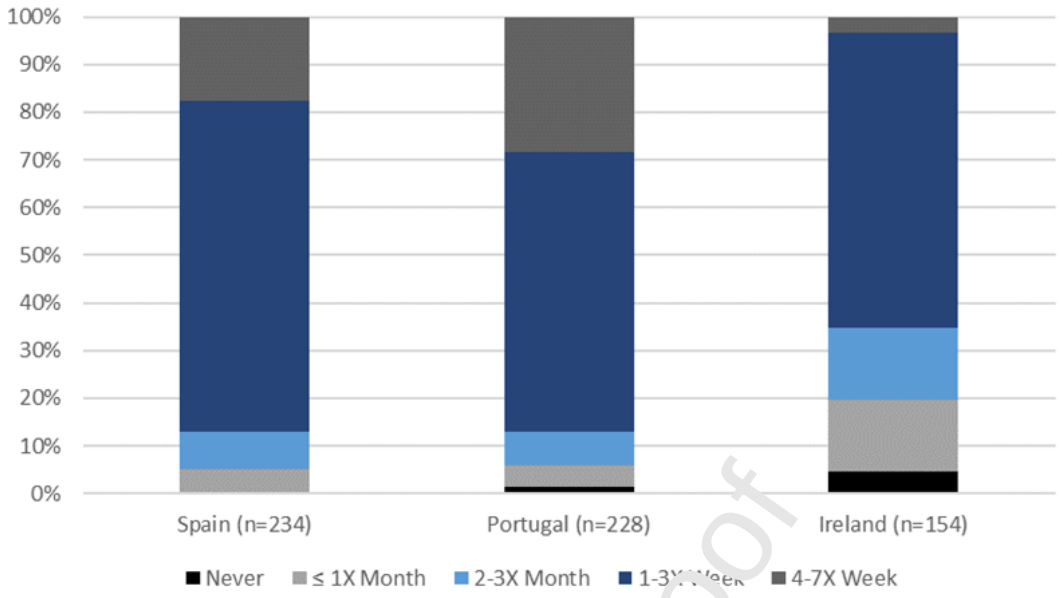


Figure 1. Relative frequency of seafood consumption in the three countries

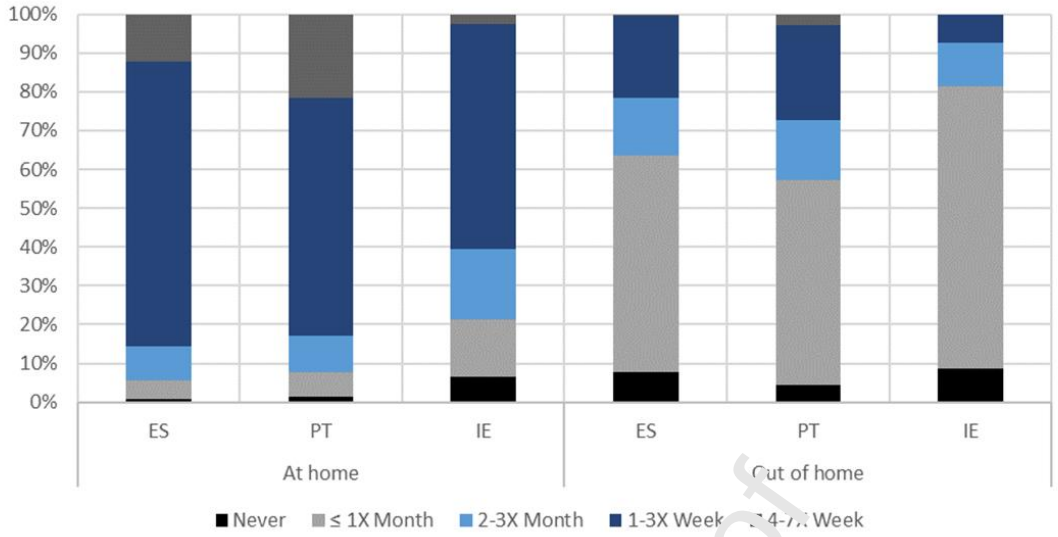


Figure 2. Relative frequency of seafood consumption in the three countries at home and out of home.

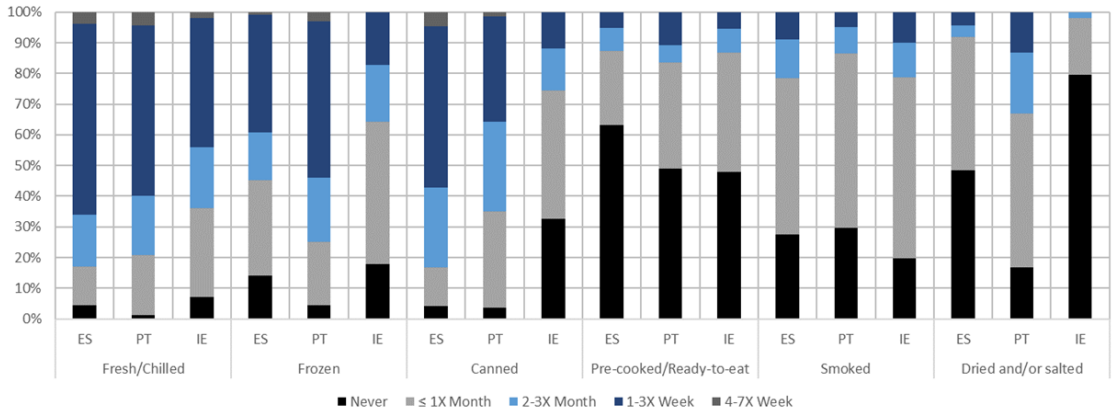


Figure 3. Realtive frequency of seafood consumption for different post-harvest processing products.

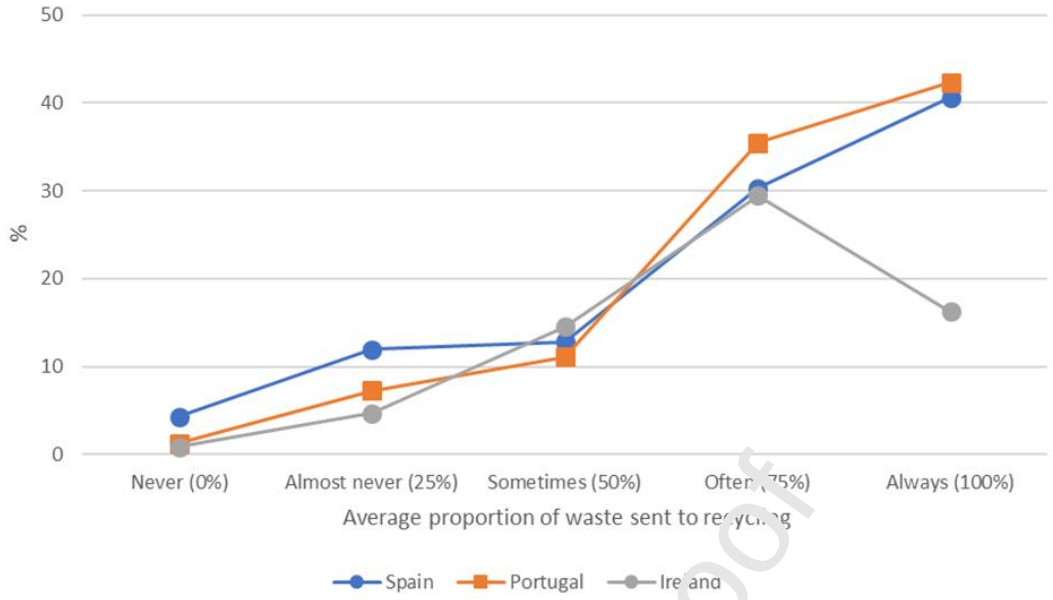


Figure 4. Percentage of respondents that perform separation of household waste of non-organic waste(i.e. glass, paper, plastic waste) to be sent to recycling in the three countries.

Author Contribution Statement

Cheila Almeida: Conceptualization; Methodology; Investigation; Data Curation; Project administration; Writing - Original Draft

Jara Laso: Methodology; Investigation; Visualization; Writing - Original Draft

David Baptista de Sousa: Methodology; Investigation; Writing - Original Draft

Ronan Cooney: Methodology; Investigation; Writing - Original Draft

Paula Quinteiro: Methodology; Writing - Original Draft

Neil Rowan: Methodology; Writing - Review & Editing

Ana Cláudia Dias: Methodology; Writing - Review & Editing

Eoghan Clifford: Methodology; Writing - Review & Editing

Rodrigo G. Reboredo: Writing - Review & Editing

María Margallo: Writing - Review & Editing

Maria Leonor Nunes: Methodology; Writing - Review & Editing

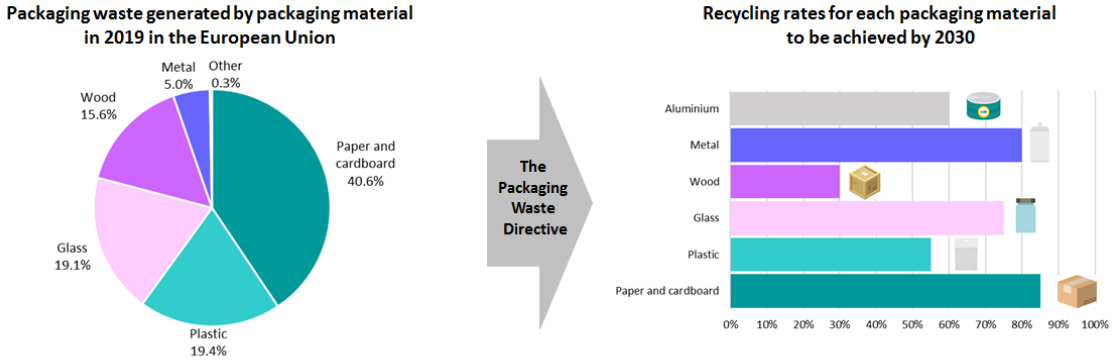
António Marques: Methodology; Review & Editing, Supervision

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Graphical abstract



Highlights

- Household practices on packaging waste relate with environmental improvements.
- Consumers are not fully aware about what type of plastics can be recycled.
- Recycling information specific for packaging materials can help consumers' behavior.
- Consumers were willing to pay more for products with more sustainable packaging.