Environmental sustainability perception toward obvious recovered waste content in paper-based packaging : an online and in-person survey best-worst scaling experiment

Environmental sustainability perception toward obvious recovered waste content in paper-based packaging: an online and in-person survey best-worst scaling experiment

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This study explores consumers' visual sustainability impressions of paper-based packaging that has incorporated obvious waste content. Two research questions were addressed concerning (i) the environmental sustainability perception of noticeable waste content in packaging and (ii) the impact of the presentation format (i.e., online versus in-person surveys) when studying these perceptions. Best-worst scaling experiments were conducted, which made respondents choose the 'most' and 'least' environmentally friendly package. Packages were designed using paperboard substrates blending either brown linerboard or white hardwood pulp with different recovered waste materials. The results showed that consumers perceive obvious waste-containing packaging as more environmentally friendly than classical packaging (with no visual waste). Samples with a brown base and agricultural waste were perceived as more sustainable compared to white packaging and the use of paper waste, respectively. In addition, the presentation format changed respondents' perception, and should therefore be carefully considered when designing surveys.

Keywords

Best-worst scaling, sustainable packaging, consumers' perception, obvious recovered waste, packaging design

1. Introduction

Together with increased global production and consumption, the use of packaging materials and packaging waste has grown. Many packages are intended for single-use applications and consequently disposed of by the final customer. The Environmental Protection Agency (EPA) reported that containers and packaging make up about 28 percent of total municipal solid waste (MSW) generation in the US, amounting to 82.2 million tons of containers and packaging waste generated in 2018. Half of these packaging products are paper-based, of which 6,440 thousand tons end up being landfilled (EPA, 2022). While striving for a sustainable and circular packaging industry, opportunities to further recycle and reuse (paper-based) waste for new packaging products exist and should be further explored.

The use of recovered waste content in packaging can reduce its environmental footprint. However, the question remains: is this also perceived as such by the customer or the end user? Comparisons between consumer judgements and environmental life cycle analysis (LCA) results indicated that consumers often rely on misleading and inaccurate beliefs to judge the sustainability of packaging (Steenis et al., 2017). A consumer can judge the package based on the structural (e.g., the packaging material), verbal, and graphical design. While striving toward more sustainable products, both the intrinsic attributes (e.g., manufacturing efficiency or organic ingredients) and the extrinsic attributes (e.g., the package) of the product play an important role (Magnier et al., 2016). Intrinsic sustainability can only be communicated via labels and logos, while extrinsic attributes have the opportunity to be redesigned. Steenis et al. (2017) demonstrated that consumers' sustainability evaluations are highly influenced by graphical packaging cues that have no actual sustainability consequences (Steenis et al., 2017). For example, the use of green color in the graphical design of a package is automatically associated with a higher level of sustainability (Pancer et al., 2017; Steenis et al., 2017).

Environmental sustainability performance has been perceived as a key product attribute, and therefore a source of potential differentiation and competitive advantage for companies (Porter and Van Der Linde, 1995). When consumers make product decisions, the environmental criterion is increasingly important (Peattie and Peattie, 2009). Multiple studies have been conducted analyzing the willingness-to-pay (WTP) for products with beneficial social and environmental performance characteristics. The majority of these research studies point to a higher premium for sustainable products, compared to their less-sustainable alternatives (Arce Salazar and Oerlemans, 2016). However, customers are growing acutely aware of "greenwashing", the practice of disclosure of false or incomplete information by an organization to present an environmentally responsible public image (Furlow, 2010). The perception of greenwashing strategies harms consumer attitudes and can lead to loss of credibility and poor purchasing decisions (Lewandowska et al., 2017; Parguel et al., 2011).

Product sustainability perception should be accounted for when developing and designing new sustainable packaging materials. Consumers should be able to easily recognize sustainable packaging based on direct cues provided by the material itself (i.e., implicit packaging cues), without the need for labels and claims (i.e., explicit packaging cues). The redesign of sustainable packaging could be achieved by adding low-intensity processed waste to the fiber furnish prior to papermaking (Chacon et al., 2022). Chacon et al. (2022) showed that by minimally processing the waste, the paper could be endowed with macroscopic and visual particles on the surface of the substrate that could communicate sustainability. It is suggested that the obvious recovered waste content within the package will help consumers to identify the product as environmentally friendly and guide consumers' purchasing decisions toward these options. Therefore, a deep understanding of consumers' attitudes toward packaging with noticeable waste content is needed. Previous research has focused on the influence of implicit packaging cues on the perception of consumers by using surveys (Granato et al., 2022). Some of these studies focused on the perception of different types of materials such plastic packaging, or a comparison between glass, plastic, and aluminum packages (De Feo et al., 2022; Weber Macena et al., 2021). However, no studies in this regard were found focusing on paper-based packaging with visually obvious waste content.

The present study focuses on both the structural and graphical design of paper-based packaging, without any information provided by labels and logos. Consumers' visual impressions on a variety of paper-based packaging materials were explored, which provides insights into consumers' beliefs on sustainable packaging. More specifically, this study aims to investigate if paper-based packaging with incorporated visually obvious paper and agricultural waste content instils positive sustainability perceptions. Consumer perception was studied by the use of stated preference (SP) methods, which rely on data that comes from consumers' responses to hypothetical questions. Previous studies have shown that the presentation format used in consumer questionnaires has a significant impact on choice (Mokas et al., 2021; Murwirapachena and Dikgang, 2021). Traditionally, SP methods rely on text descriptions or pictures of the assessed good or service. However, the evaluation of the packaging materials might change when packaging materials are shown to consumers in real life.

Two research questions are addressed in the present study: (1) Does the obvious recovered waste content in the packaging influence the perception of how environmentally sustainable the package is? And (2) Does the presentation format (online versus in-person surveys), which is used to study consumers' preferences, change the packaging perception? This study aims to gain an understanding of consumers' choices regarding sustainable packaging and to create a unique dataset comparing both online and in-person survey responses.

2. Materials and Methods

2.1 Materials

Recycled brown linerboard (RL) (S-19318, Uline, Georgia, US) and elemental chlorine-free bleached white hardwood pulp (BHW) (International Paper, US) were used as raw materials for paperboard making. Brown (unbleached) and white (bleached) pulp represent the two type of fibers used in paper-based packaging applications (Wu, 2021). Paper and agricultural waste were utilized to endow the paperboards with a visually obvious contaminant content. Copy paper of 75 g/m^2 (Husky® copy, Domtar, South Carolina, US), coupon inserts of 45 g/m^2 composed of lightweight coated (LWC) paper collected from a local grocery store (North Carolina, US), and green and pink paper of 89 g/m^2 (Astrobrights, Georgia, US) were selected as paper waste materials. The paper waste selection was based on global paper production by category. According to Tiseo (2022), printing- and writing paper is the second largest paper consumed globally and, therefore, one of the major types of paper waste produced. Switchgrass (SW) collected from a local source (North Carolina, US) and cocoa bean shells purchased from Hull Farm (Wisconsin, US) were chosen as agricultural waste. Switchgrass is an abundant grass native to North America that shows a high growth rate, even under poor soil conditions (Wang et al., 2020). Cocoa bean shells, on the other hand, are a by-product of cocoa production, representing 12% of the raw material (Gómez Hoyos et al., 2020). Both agricultural wastes represent an abundant, renewable, low-cost feedstock that can be used for high-value products such as packaging

Images of the waste materials used in this study are shown in Figure S 1 in the supplementary information (SI).

2.2 Research methodology and design

Within this research study, the best-worst scaling (BWS) method was applied to investigate the environmental sustainability perception toward obvious recovered waste content in paper-based packaging. BWS is a stated preference (SP) method, developed by Louviere and Woodworth in 1990 (Louviere and Woodworth, 1990). The BWS method allows respondents to evaluate all pairwise combinations of alternatives presented in several subsets leading to the modeling assumption that their "best" and "worst" choices represent the maximum difference in utility between all attributes (Parvin et al., 2016). For that reason, the BWS method is also referred to as the "maximum difference scaling" (maxdiff) method. BWS effectively avoids scaling interpretation problems of traditional rating scales (such as the Likert scale) (Finn and Louviere, 1992). Also, compared to rating a product on a 5- or 7-point scale, choosing a product from a set of alternatives is considered a more 'natural' task that consumers undertake daily, for example, when shopping at a store (Chapman and Feit, 2019).

A BWS experiment uses a balanced incomplete block design (BIBD), in which each alternative appears equally often, and co-appears equally often with the other alternatives (Louviere et al., 2013). Within this study, the alternatives consisted of eleven different packaging alternatives, which were each shown five times over eleven different subsets (Table 1). Within each subset, the respondents were asked to indicate the "most" and "least" environmentally friendly box.

Table 1. BIBDs with 11 packaging alternatives (1-11) in 11 different subsets (A-K).

Subset	Packaging alternatives				
A	1	2	7	10	8
B	10	3	9	6	7
C	9	7	5	4	1
D	4	5	10	2	6
E	2	8	3	9	4
F	6	1	8	5	3
G	5	10	11	8	9
H	11	4	1	3	10
I	8	6	4	7	11
J	7	3	2	11	5
K	9	11	6	1	2

2.3 Presentation formats

The paper-based boxes were evaluated via two different presentation formats. First, an online BWS experiment was launched using 3D images of the boxes. Respondents viewed the box images on their personal desktop or laptop, and were asked not to take the survey on their smartphone. The use of pictures might be representable for the graphical design, but the structural design and the packaging material are expected to be less pronounced within a picture relative to viewing the actual object in-person. Therefore, a second presentation format was added using an in-person survey in which small packaging boxes were shown to the respondents. Both the in-person and online BWS experiments used the BWS design presented in Table 1. In the online survey, alternatives within a subset were randomized as well as the subsets themselves. In the in-person survey, the alternatives within a subset were shown on a fixed position to every respondent, but it was ensured that this position (from 1 to 5) differed over the different subsets so that positional bias was avoided. Also, every respondent was asked to judge the subsets (from A to K) in a different order to make sure that the subsets themselves were randomized (Figure S 2 in SI).

2.4 Preparation of the packaging samples

The boxeswere produced from paperboards containing RL and BHW as base material and partially disintegrated recovered waste of different sources (i.e., copy paper, coated paper, colored paper, switchgrass, and cocoa bean shells). For paperboards-making, the RL and BHW were each fully disintegrated in water using a pulp disintegrator (Testing machine Inc., Delaware, US) at 3000 rpm for 5 minutes. The paper waste was shredded to strips of 5 mm width. The agricultural waste was mechanically ground to a particle size of 2 mm using a Wiley laboratory mill (Model No. 3, Arthur H. Thomas, Philadelphia, US) prior to paperboard making.

The waste was then mixed with the base materials (RL or BHW), as described in Table 2, using the pulp disintegrator at 3000 rpm for 30 seconds to partially disintegrate the waste. Additionally, shredded RL and the BHW were combined to prepare paperboards with BHW as a base material with visible particles of RL. The weight ratio of the waste used for the production of the paperboards was 40 wt%, except for the green and pink paper where 10 wt% of waste was used. The pulp slurry containing the blend of base material and partially disintegrated waste was utilized to produce paperboard specimens with a targeted basis weight of 240 g/m^2, adapting the TAPPI 205 Sp-02 (2006) standard to a lab-scale rectangular handsheet former. The paperboards were dried using a drum dryer (Chromalox 2110, Adirondack Machine, New York, US) at 100 °C (± 5 °C) and then stored at 50% relative humidity (RH) and 23 °C before paper testing according to TAPPI 402 sp-98 (1998) standard.

Table 2. Composition of waste-containing paperboard samples. RL = recycled linerboard and BHW = bleached hardwood pulp.

Sample Number	Sample Identification	Base Material	Recovered waste	Waste Content* (wt%)
1	RL/Control	Recycled linerboard	-	0
2	RL/Cocoa	Recycled linerboard	Cocoa bean shell	40
3	RL/Grass	Recycled linerboard	Switchgrass	40
4	RL/Pink	Recycled linerboard	Pink paper	10
5	RL/Coated	Recycled linerboard	Coated paper	40
6	RL/Copy	Recycled linerboard	Copy paper	40
7	RL/Green	Recycled linerboard	Green paper	10
8	BHW/Control	Bleached hardwood pulp	-	0
9	BHW/Grass	Bleached hardwood pulp	Switchgrass	40
10	BHW/Copy	Bleached hardwood pulp	Copy paper	40
11	BHW/RL	Bleached hardwood pulp	Recycled linerboard	40

*based on oven-dry mass

The 11 paperboard samples, i.e., two control samples containing only base materials (RL and BHW) and nine paperboards containing 10 wt% or 40 wt% of paper and agricultural waste, were scanned using a flat-bed scanner (Epson Perfection 2400 photo, California, US). The digitized pictures were used for modeling 3D box images using SketchUp computer program. The box images together with an enlarged picture of the corresponding paperboard (Figure 1) were used to evaluate consumers' perception through an online survey.

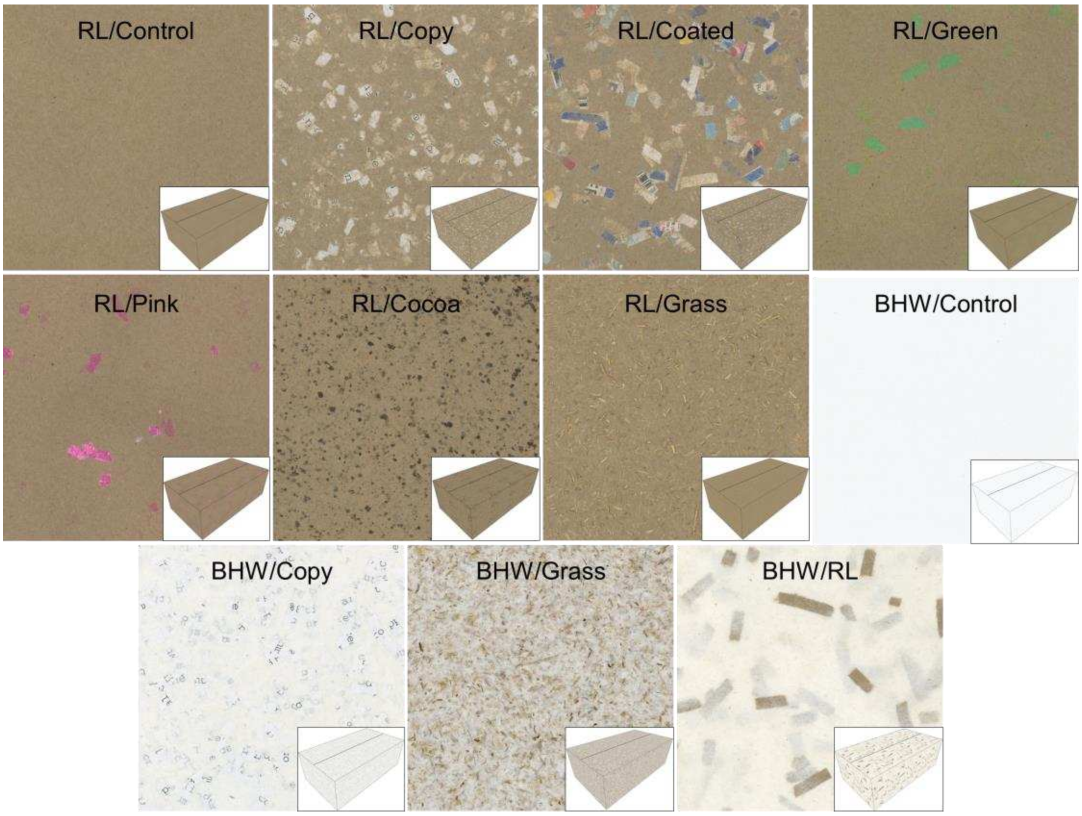

Figure 1. Paperboard and box images used for the online survey. The box images were created with a drawing package but included the real image of the paperboard.

Additionally, 11 paper-based real boxes of 7.0 x 4.5 x 5.5 cm (L x W x H) were made with the produced paperboards (Figure 2). The base of the boxes was sealed with glue, mainly containing acrylic polymer, and a piece of regular tape. The real samples were used for the in-person survey.

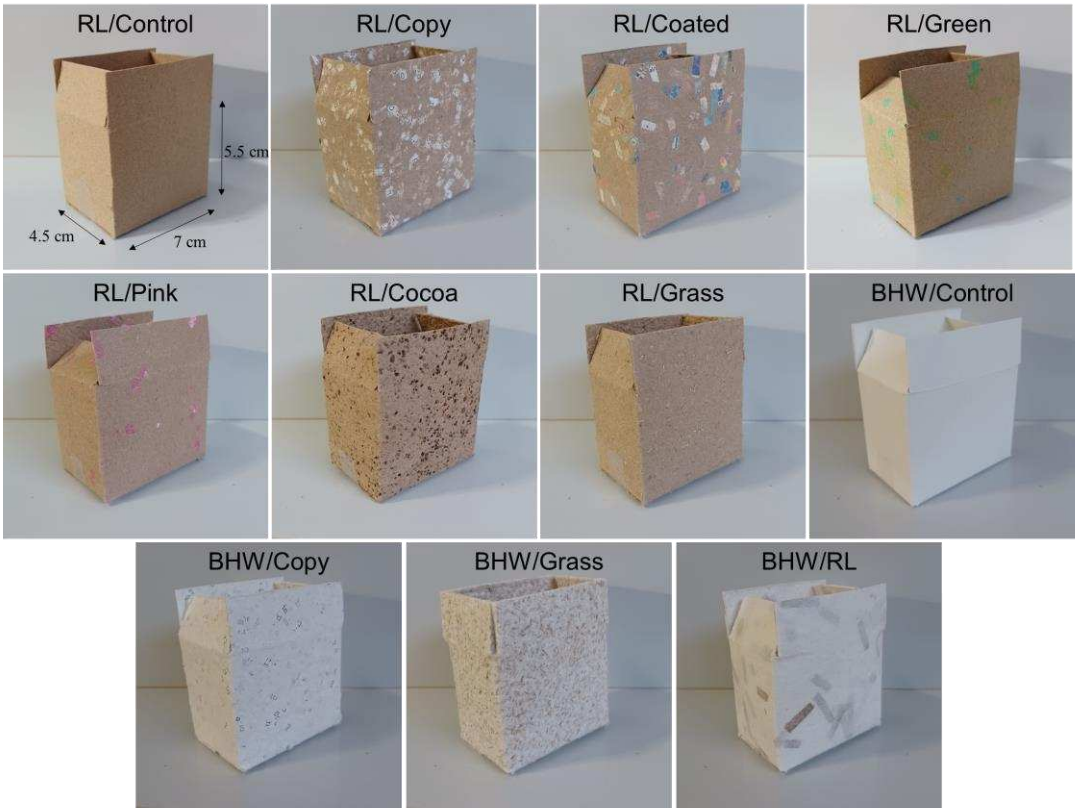

Figure 2. Boxes used for the in-person survey.

2.5 BWS data analysis

The BWS data was analyzed using a counting and a modeling approach. First, a counting approach counts the number of times each box was chosen as the most or least environmentally friendly alternative. This counting analysis results in B (best), W (worst), and BW (best-worst) scores (Flynn and Marley, 2014; Van Schoubroeck et al., 2019). The BW score of package i is calculated according to Equation (1). The calculation of BW scores enables considerable insights at the level of the individual respondent (Flynn and Marley, 2014).

$$BW_i \; score = \sum B_i - \sum W_i \qquad (1)$$

Second, a conditional logit (CL) model is estimated based on respondents having a certain utility (v) (i.e., a certain value) for each package. Respondents are assumed to select the best and worst packages based on the largest difference between their utilities (i.e., the maximum difference model). This conditional logit model will estimate the average preference (Pr) for a certain package among the individuals. Under these assumptions, the probability to select package i as the best and j as the worst is expressed in Equation (2). For interpretation purposes, a share of preference (SP) for package i based on the conditional logit model choice rule was also calculated according to Equation (3) (Cohen and Neira, 2004). The share of preferences must sum to one across all packaging alternatives. The SP_i reports the importance of package i on a ratio scale, meaning that if SP_i is twice that compared to the SP of another package, it can be said that package i is twice as preferred than the other package (Lusk and Briggeman, 2009).

$$\Pr(i,j) = \frac{\exp(v_i - v_j)}{\sum_{k=1}^{m}\sum_{l=1,k\neq l}^{m}(v_k - v_l)} \qquad (2)$$

With m = the amount of packages in one choice subset, equals '5' in this study.

$$SP_i \frac{\exp{(v_i)}}{\sum_{t=1}^{T}\exp{(v_t)}} \qquad (3)$$

2.6 Paperboard testing

To find possible correlations between the BWS preference results and the paperboard properties, characterization of the paperboard was performed. The basis weight of the paperboards was determined using a high precision scale and dividing the mass of each sample by the area. The thickness was measured using a micrometer (Lorentzen & Wettre, Sweden). The bulk (inverse of density) was determined by dividing the thickness of the paperboard specimens by the basis weight. Roughness was measured using the Parker Print Surf roughness tester (SE 115, Lorentzen & Wettre, Sweden) using a contact pressure of 1.0 MPa according to TAPPI 555 pm-94 (1997). Bending resistance (stiffness) was evaluated using a Taber V-5 stiffness tester (Model 150-B, Taber Instrument Corporation, North Tonawanda, N.Y., US) (TAPPI 489 om-08, 2013).

Surface topography of all the paperboard samples was performed using a confocal laser scanning microscope (Keyence VK-X1100, Osaka, Japan). Color analysis was performed using TinEye Color Extraction tool which is a free web service that extracts color palette for all the colors identified in an uploaded image (TinEye, 2022). The average particle size of paper and agricultural waste was measured from scanned paperboards (Epson Perfection 2400 photo) at a resolution of 800 dpi followed by image analysis using ImageJ software (National Institutes of Health and Laboratory for Optical and Computational Instrumentation, US).

3. Results and discussion

3.1 Data collection

The online survey was launched using a respondents' database from the North Carolina State Sensory Service Center on November 1, 2021 (survey shown in SI S 3). The in-person surveys were launched at three different locations in Raleigh, North Carolina, i.e., university campus, a Harris Teeter supermarket, and the NC State Farmers' Market, throughout November of 2021. A total of 506 respondents filled out the online survey and 228 respondents the in-person survey. A total of 19 (3.75%) online respondents and 17 (7.46%) in-person respondents were identified as "bad" respondents. "Bad" respondents were defined as respondents who did not understand the BWS experiment or answered randomly probably with the sole focus to receive the final incentive (i.e., a gift card).

To identify these "bad" respondents, the time to complete the survey and their straight-lining behavior was examined. Responses were deleted based on three criteria: (1) if the survey took less than three minutes, (2) if a respondent scored package i as "most" and package j as "least" in subset x, and at the same time scored package i as "least" and package j as "most" in subset y, and (3) if a respondent scored more than three packages as both "most" and "least" during the full survey. A total sample of 487 online responses and 211 in-person responses were used for final data analysis. Socio-demographical information concerning the included participants and their environmental awareness is provided in SI (S 4 and S 5).

3.2 General packaging preferences

Table 3 summarizes the results of both the counting and modeling analysis of the online sample data. The B (best) and W (worst) scores show the frequency of the packages chosen as the most and least environmentally friendly alternatives. Based on the BW (best-worst) scores, the top three chosen packages consisted of the RL/Coated, followed by the RL/Copy and RL/Grass packages. The lowest BW scores were calculated for the two control packaging samples (RL/Control and BHW/Control) without contaminants. In addition to the aggregated BW scores, the BW scores per respondent per package were calculated and used in further analysis to represent the preferences per respondent. The results of the counting analysis were confirmed by the conditional logit (CL) model (Table 3). All the means of the packaging alternatives with obvious recovered waste content were positive and significant at $p < 0.01$. This indicates that these packaging alternatives are all more preferred than the RL/Control package, which is used as the benchmark having a coefficient of zero. The mean for BHW/Control is negatively significant at $p < 0.01$, meaning that it is considered less preferred compared to the RL/Control by the respondents. Figure 3 shows a preference ranking of the packages, based on the results of the share of preferences for each package, reflecting the preference of respondents toward the packages with obvious recovered waste content.

Table 3. Online best-worst scaling results (n = 487).

	Counting analysis			Conditional logit model				
	Best	**Worst**	**BW**	**Mean**	**P value**		**Standard errors**	**Share of preference**
RL/Coated	1386	120	1266	2.428	< 2e-16	***	0.0560	0.2738
RL/Copy	1034	66	968	2.104	< 2e-16	***	0.0555	0.1979
RL/Grass	851	141	710	1.799	< 2e-16	***	0.0547	0.1459
BHW/Grass	655	246	409	1.467	< 2e-16	***	0.0548	0.1047
BHW/Copy	547	375	172	1.071	< 2e-16	***	0.0533	0.0705
RL/Cocoa	386	265	121	1.034	< 2e-16	***	0.0530	0.0679
BHW/RL	170	383	-213	0.509	< 2e-16	***	0.0518	0.0439
RL/Green	122	504	-382	0.462	< 2e-16	***	0.0529	0.0383
RL/Pink	73	622	-549	0.150	3.1e-03	***	0.0508	0.0281
RL/Control	257	871	-614	0	-		-	0.0241
BHW/Control	85	1973	-1888	-1.599	< 2e-16	***	0.0556	0.0049

*** p < 0.01

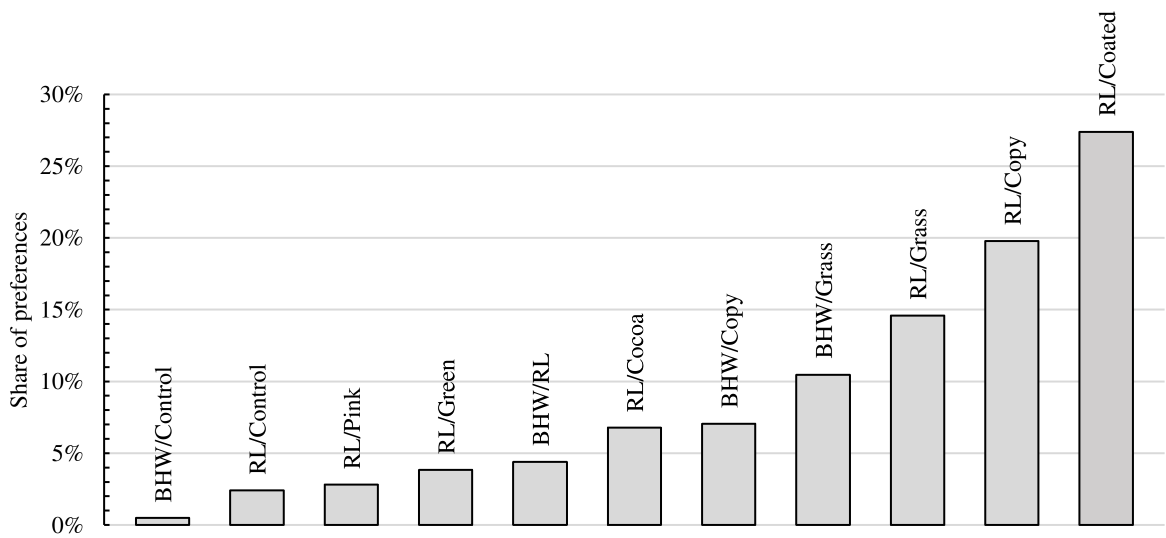

Figure 3. Share of preferences for the packaging materials, from least preferred (left) to most preferred (right) package. Results from the online survey based on CL model.

Table 4 summarizes the results of both the counting and modeling analysis of the in-person sample data. The B and W scores show the frequency of the packages chosen as the most and least environmentally friendly alternatives. Based on the BW scores, the top three packages consisted of the RL/Grass, followed by the RL/Cocoa and BHW/Grass packages. The lowest BW scores were again given to the two control samples, the RL/Control and BHW/Control. The results of the counting analysis were again confirmed by the conditional logit model (Table 4). All the means were significant at $p < 0.05$. Figure 4 shows a preference ranking of the packages, based on the results of the share of preferences for each package, visualizing the preference of respondents toward the packages with obvious recovered waste content.

Table 4. In-person best-worst scaling results (n = 211).

	Counting analysis			Conditional logit model				
	Best	**Worst**	**BW**	**Mean**	**P value**		**Standard errors**	**Share of preference**
RL/Grass	392	71	321	1.219	< 2e-16	***	0.0726	0.1714
RL/Cocoa	329	82	247	1.035	< 2e-16	***	0.0718	0.1426
BHW/Grass	399	181	218	0.973	< 2e-16	***	0.0720	0.1339
RL/Copy	236	60	176	0.876	< 2e-16	***	0.0724	0.1217
RL/Coated	241	100	141	0.780	< 2e-16	***	0.0719	0.1104
BHW/Copy	143	201	-58	0.298	3.1e-05	***	0.0716	0.0682
RL/Pink	79	158	-79	0.220	1.8e-03	***	0.0707	0.0631
BHW/RL	94	198	-104	0.170	1.5e-02	**	0.0700	0.0600
RL/Green	110	226	-116	0.156	2.8e-02	**	0.0710	0.0592
RL/Control	200	369	-169	0	-		-	0.0506
BHW/Control	98	675	-577	-0.995	< 2e-16	***	0.0721	0.0187

*** p < 0.01; ** p < 0.05

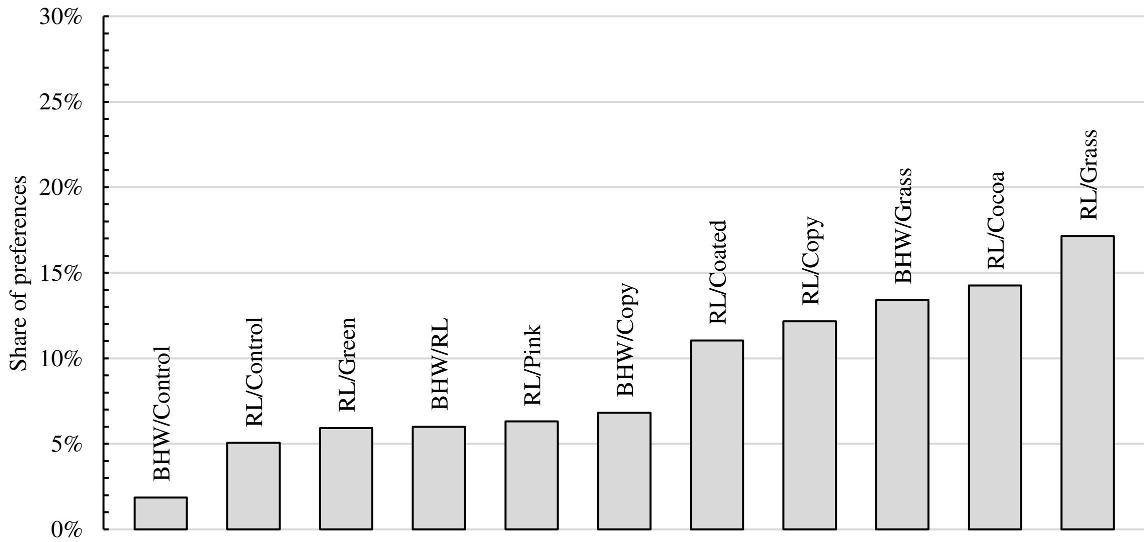

Figure 4. Share of preferences for the packaging materials, from least preferred (left) to most preferred (right) package. Results from the in-person survey based on CL model.

A comparison between Figure 3 and Figure 4 indicates a difference in respondents' preferences between the online and in-person sample. To check if there was a difference between the two samples, Mann-Whitney-Wilcoxon Tests were performed per package (Table 5). The BW scores per respondent were used to measure the preference toward a certain package. The null hypothesis states that the BW scores of the online and the in-person sample are identical populations. When the P value is less than the 0.05 significance level, the null hypothesis is rejected. For the packages RL/Cocoa, RL/Pink, RL/Coated, RL/Cocoa, BHW/Control, BHW/Grass, and BHW/Copy, significant differences were noted between the online and in-person sample.

Table 5. Results of Mann-Whitney-Wilcoxon tests per package when comparing the BW scores between the online and in-person sample, and the direction of change in preference when switching from the online to the in-person presentation format (with ↑ = "preference going up", and ↓ = "preference going down").

Sample ID	**P value**		**Direction of change in preference from online to in-person format**
RL/Control	3.2e-01		
RL/Cocoa	6.1e-11	***	↑
RL/Grass	4.1e-01		
RL/Pink	3.5e-06	***	↑
RL/Coated	2.2e-16	***	↓
RL/Copy	2.2e-16	***	↓
RL/Green	5.2e-01		
BHW/Control	5.4e-10	***	↑
BHW/Grass	7.4e-02	*	↑
BHW/Copy	2.0e-04	***	↓
BHW/RL	7.0e-01		

*** $p < 0.01$; * $p < 0.1$

At the end of both the online and in-person surveys, the respondents were asked to rate the BWS experiment on a five-point Likert scale, going from 'very easy' to 'very difficult' (Figure 5). The respondents in the online survey generally perceived the experiment as more difficult compared to the in-person participants. Within the survey, the online participants were able to explain their rating in an open comment box. These responses were analyzed using open coding analysis, defining different keywords within the answers (Strauss and Corbin, 1998). The open question box was not provided in the in-person survey due to time constraints.

Overall, respondents that considered the survey difficult and responded with low ratings referred to certain 'knowledge gaps', which prevented them from making informed decisions. These were related to the lack of knowledge they had on the materials, processing, end-of-life, or sustainability assessment itself. Also, they often acknowledged that visual appearances can be deceiving, and they felt uncomfortable judging the products based on visual impressions alone. This could indicate the awareness of respondents toward greenwashing in marketing. In addition, some of them mentioned the need to see, feel, or smell the boxes in-person. Respondents that considered the survey easy and responded with high ratings indicated that they made the choices between the packages based on their own judgements on the perceived feedstocks, the color of the materials, processing, and the recognition of obvious recovered waste content within the boxes. An overview of the coding analysis is provided in SI (Figure S 6).

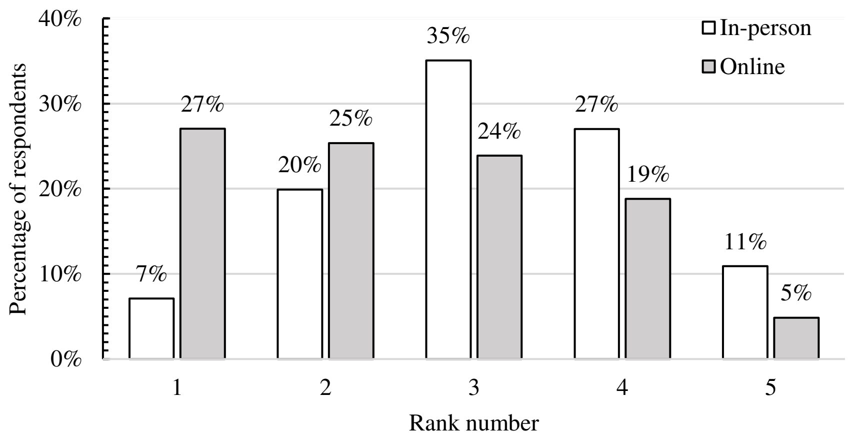

Figure 5. Rating the choice experiment from “1” = “very difficult” to “5” = “very easy”.

3.3 Preferences related to respondents’ characteristics

The sustainability rankings of packages, as shown in Figure 3 and Figure 4, might differ based on respondents’ characteristics such as gender and age. To analyze these differences, the conditional logit model was estimated again for certain sub-groups in the sample (i.e., ‘female’ versus ‘male’, ‘born in 1988 or after’ versus ‘born before 1988’). Table 6 shows the differences in rankings, based on the share of preferences, between females and males for both the online and the in-person survey. The packaging samples shaded in grey represent the ones that change ranking position when comparing both genders. For example, the BHW/Copy and RL/Cocoa packages switch ranking positions when calculating the preferences for females compared to males. However, these switches are caused by rather small differences between the preference results.

Table 7 shows the differences in rankings between the age groups. For the online sample, no large differences were noted between both age groups. For the in-person sample, a clear lower preference was given to RL/Control and a higher preference for BHW/grass in the age category ‘born in 1988 or after’. This can be confirmed by the boxplots of the BW scores in SI (S 7 in SI). However, it should be noted that the differences between the share of preferences for the age category ‘born before 1988’ in the in-person survey are relatively low.

Mann-Whitney-Wilcoxon tests were performed to verify if the differences between both gender and age categories were significant. The BW scores per respondent per package of both the online and in-person samples together were used as an indication of the individual’s preference toward a certain package. No significant P values were found between individual preferences and gender. However, the null hypothesis (stating that the populations are the same) can be rejected when comparing both age categories for the RL/Control, RL/Pink, RL/Green, BHW/Grass, and BHW/Copy packages (S 8 in SI). Additional boxplots can be consulted visualizing the BW scores for groups with different educational backgrounds (Figure S 7 in SI). Significant differences were noted between these education-based groups for the RL/Control, RL/Grass, BHW/Control, BHW/Grass, and BHW/Copy packages (S 8 in SI).

Table 6. Gender differences in preference results based on CL model (columns are sorted from highest to lowest share of preferences). Packaging samples shaded in grey represent the ones that change ranking position.

Online				**In-person**			
Female (n=286)		**Male (n=194)**		**Female (n=121)**		**Male (n=90)**	
RL/Copy	0.2726	RL/Copy	0.2722	RL/Grass	0.1654	RL/Grass	0.1793
RL/Coated	0.2063	RL/Coated	0.1858	RL/Cocoa	0.1467	BHW/Grass	0.1557
RL/Grass	0.1491	RL/Grass	0.1409	RL/Coated	0.1299	RL/Cocoa	0.1366
BHW/Grass	0.0990	BHW/Grass	0.1176	BHW/Grass	0.1195	RL/Coated	0.1107
BHW/Copy	0.0701	RL/Cocoa	0.0723	RL/Copy	0.1120	RL/Copy	0.1077
RL/Cocoa	0.0643	BHW/Copy	0.0718	BHW/Copy	0.0680	BHW/Copy	0.0680
BHW/RL	0.0435	BHW/RL	0.0440	RL/Green	0.0651	BHW/RL	0.0644
RL/Green	0.0386	RL/Green	0.0371	RL/Pink	0.0644	RL/Pink	0.0610
RL/Pink	0.0259	RL/Pink	0.0316	BHW/RL	0.0568	RL/Green	0.0516
RL/Control	0.0256	RL/Control	0.0217	RL/Control	0.0534	RL/Control	0.0467
BHW/Control	0.0050	BHW/Control	0.0049	BHW/Control	0.0188	BHW/Control	0.0183

Table 7. Age differences in preference results based on CL model (columns are sorted from highest to lowest share of preferences). Packaging samples shaded in grey represent the ones that change ranking position.

Online				**In-person**			
Born in 1988 or after		**Born before 1988**		**Born in 1988 or after**		**Born before 1988**	
RL/Copy	0.2700	RL/Copy	0.2787	BHW/Grass	0.2016	RL/Grass	0.1599
RL/Coated	0.1932	RL/Coated	0.2041	RL/Grass	0.1768	RL/Cocoa	0.1311
RL/Grass	0.1503	RL/Grass	0.1398	RL/Cocoa	0.1464	RL/Coated	0.1109
BHW/Grass	0.1151	BHW/Grass	0.0915	RL/Coated	0.1271	RL/Control	0.1044
BHW/Copy	0.0769	RL/Cocoa	0.0754	RL/Copy	0.1144	RL/Copy	0.0976
RL/Cocoa	0.0624	BHW/Copy	0.0622	BHW/Copy	0.0690	RL/Green	0.0857
BHW/RL	0.0428	BHW/RL	0.0450	BHW/RL	0.0567	RL/Pink	0.0837
RL/Green	0.0364	RL/Green	0.0407	RL/Pink	0.0411	BHW/Grass	0.0825
RL/Pink	0.0252	RL/Pink	0.0320	RL/Green	0.0365	BHW/Copy	0.0597
RL/Control	0.0228	RL/Control	0.0257	RL/Control	0.0211	BHW/RL	0.0541
BHW/Control	0.0049	BHW/Control	0.0049	BHW/Control	0.0092	BHW/Control	0.0303

3.4 Preferences related to packaging properties

Product characteristics, such as waste origin, base material, color, etc., might influence the online and in-person sustainability perception of the respondents. By visualizing and correlating the respondents' preference scores (i.e., the BW scores per respondent) with different paperboard properties, insights can be provided on the sustainability perception of product properties and the difference between online and in-person perceptions. Figure 6 shows four different boxplots, where the categorical variables "waste origin" ("control", "paper", and "agricultural") and "base material" ("BHW" and "RL") are mapped on the y-axis and the numeric variable "BW scores" on the x-axis. The boxplots of "waste origin" (Figure 6) show again a lower sustainability perception for the control boxes, and a higher preference for the boxes with obvious recovered waste content regardless of the format of the survey, i.e., online or in-person. For the online survey, it can be noted that there is almost no overlap between the BW scores of the control boxes and the boxes with the obvious recovered waste content. In addition, the correlations between the type of waste and the BW scores were quantified using

Spearman's rho calculations. The control boxes were omitted from the dataset to create a direct comparison between obvious recovered paper and agricultural waste. The correlation coefficients indicate a weak, positive relationship between the use of agricultural waste and its sustainability perception. This correlation is relatively stronger for the in-person sample (i.e., a correlation of 0.307) compared to the online sample (i.e., a correlation of 0.105). Agricultural waste was composed of brown particles with an average particle size of 0.006 cm^2 while the paper waste was composed of bigger particles (c.a. 0.1 cm^2) of brighter colors such as white, blue, neon green, and neon pink (Table 8). Previous researched showed that consumers associate dull colors, especially brown and green, with sustainability (Herbes et al., 2020; Magnier and Crié, 2015), thus it could be inferred that the color of the agricultural waste could have influenced consumers' preferences toward the boxes containing this type of waste. Paper waste, on the other hand, with brighter colors could have been perceived as more synthetic and therefore perceived as less environmentally friendly.

The boxplots on "base material" (Figure 6) shows a slightly lower sustainability perception for the BHW based boxes compared to the RL based boxes. A comparison between the online and in-person survey samples shows almost no difference between the presentation formats, except for a neglectable difference in the 95% confidence interval around the median (represented by the notch). The correlations between the base material and the BW scores were quantified using Spearman's rho calculations. Both correlation coefficients indicate a weak, positive relationship between the brown RL based packaging and its environmental friendliness, with correlations of 0.208 for the online sample and 0.187 for the offline sample, with no remarkable difference between the presentation formats. However, the preference for RL based boxes becomes more apparent when a direct comparison between RL and BHW boxes containing the same waste was performed (Figure 7). For the control boxes, as well as the boxes containing switchgrass, and copy paper, RL was always preferred over BHW base material. Other academic studies, that focused on neat paper-based packaging with no obvious waste content appearance, have shown that eco-consciousness people prefer brown paper-based packaging over other materials (Liem et al., 2022), with this parameter being a decisive factor in their purchasing decision (Medinskaia, 2020). Brown (unbleached) paper could be perceived as more natural, less processed, and therefore more environmentally friendly which would explain the preferences of RL paperboards over the BHW ones.

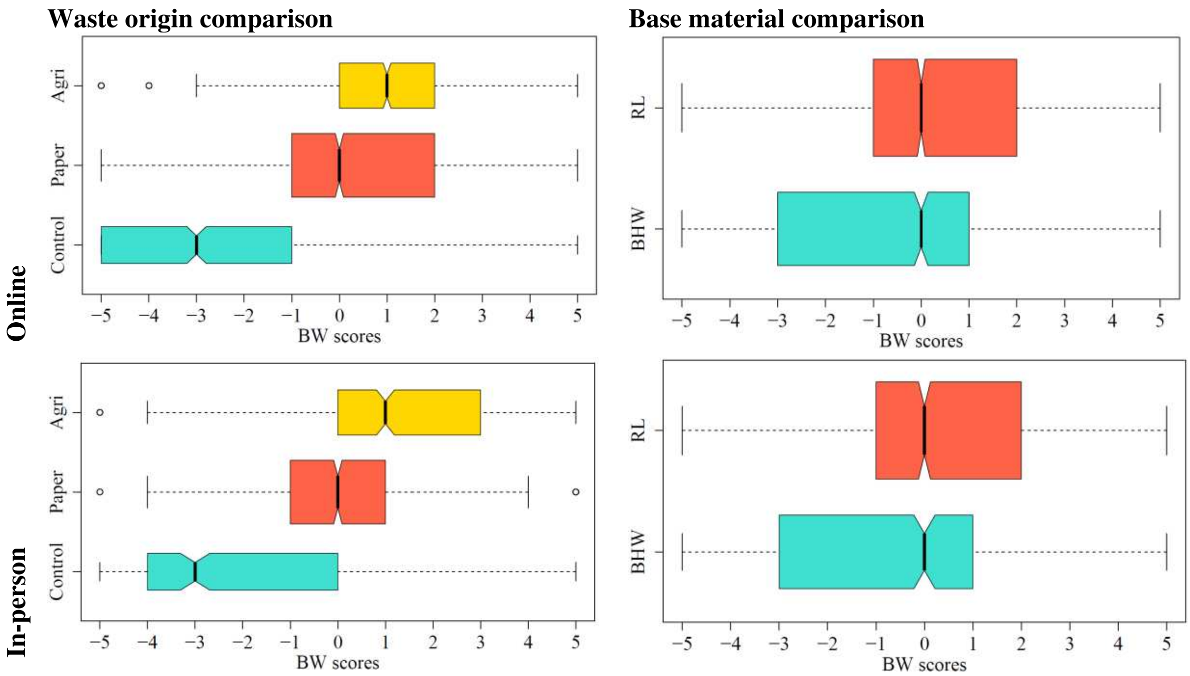

Figure 6. BW (best-worst) scores for both waste origin (“control”, “paper”, and “agricultural”) and base material (“BHW” and “RL”), with “○” indicating the outliers, the thin vertical lines indicating the maximum and minimum values (without outliers), the colored rectangles indicating the values of the upper quartile and the lower quartile, and the thick vertical line in the colored rectangles indicating the median. The 95% confidence interval around the median is represented by the notch in the colored rectangle.

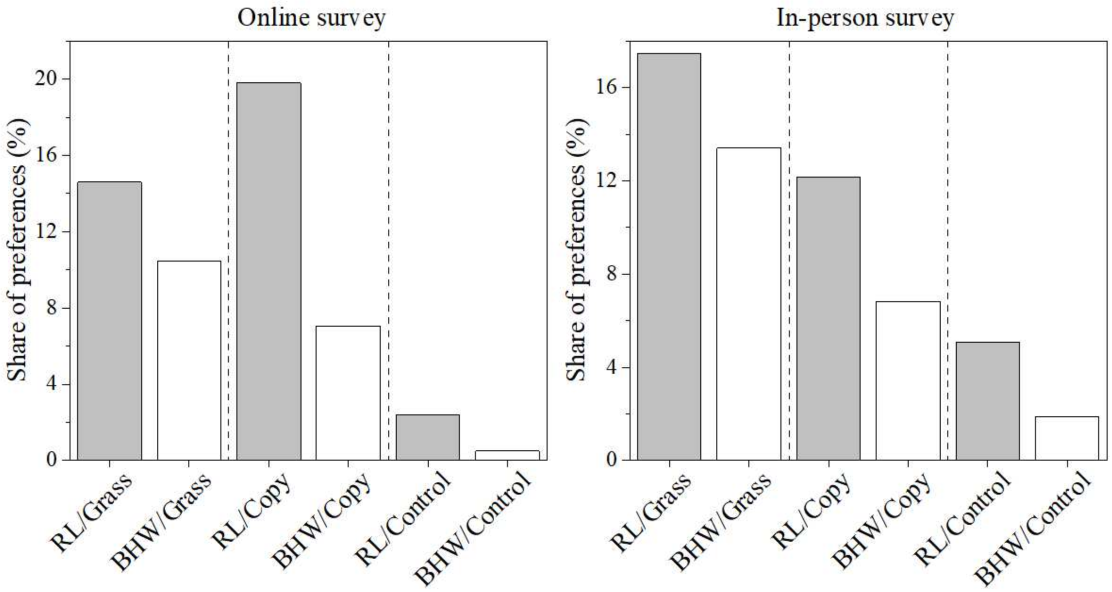

Figure 7. Comparison between packaging’ base materials (RL and BHW) having the same type of waste.

Table 8. Paper and agricultural waste characteristics.

Waste origin	Waste	Particle Size (cm^2)	Color
Paper	Copy paper	0.103 ± 0.003	65% white, 35% black
	Coated paper	0.109 ± 0.001	Multicolored (blue (59%), pink (17%), green (11%), and yellow (13%))
	Neon green paper	0.117 ± 0.023	Green
	Neon pink paper	0.119 ± 0.026	Pink
Agricultural	Switchgrass	0.006 ± 0.001	Light brown
	Cocoa bean shells	0.006 ± 0.001	Dark brown

Apart from the waste origin and the base material, other paperboard properties could have influenced consumers’ preferences between the different boxes and the presentation formats. Figure 8 shows the thickness, bulk, roughness, and bending stiffness of the different paperboard samples, and Figure 9 shows the correlation between the respondents’ preferences (based on the CL model) and the mentioned paperboard properties. For the in-person survey (Figure 9b, d, and f) there is a positive (Pearson) correlation between the share of preferences and the thickness, bulk, and roughness of the paperboard specimens, showing r values of 0.69, 0.72, and 0.91, respectively. Thicker, bulkier and especially rougher waste-containing paperboards, i.e., RL/Cocoa, RL/Grass, and BHW/Grass, were perceived as the most environmentally sustainable samples. Roughness had the strongest correlation of the aforementioned properties, and could have potentially influenced respondents’ decisions.

Although respondents were not allowed to touch the samples, differences in the texture between the in-person samples were visually noticeable as can be supported by the surface topography images depicted in Figure S 9 in SI. The topographic maps of the paperboards containing agricultural waste showed the most heterogeneous and roughest surfaces with non-uniform and prominent peaks and valley distributions. However, the question remains to which degree the consumers could have identified the differences in roughness without physical interaction with the samples. Also, a negative and strong correlation (r = -0.71) between the bending stiffness and the sustainable appearance of the boxes was observed (Figure 9h). Boxes showing a stiffer appearance were less preferred by the respondents. However, without physical interaction with the samples, bending stiffness might have been difficult to identify by the survey respondents. Prior to calculating the Pearson correlation coefficient, a normal distribution of the variables was verified through the Goodness-of-fit test using the Shapiro-Wilk method. Although the results from the test confirmed that the variables followed a normal distribution, the Pearson correlation coefficients calculated should be interpreted with discretion since the size of the sample was small (n=11) and both statistical tests (i.e., goodness-of-fit and Pearson correlation) are sensitive to the sample size.Results from the online survey showed a weak relationship between respondents' preferences and the physical properties of the paperboards, reporting r values of 0.27, 0.26, 0.48, and 0.43 for thickness, bulk, roughness, and bending stiffness, respectively (Figure 9a, c, e, and g). The r values for the online survey were all lower than the corresponding in-person values. The differences between the correlation of the paperboard properties with the sustainable perception of the boxes in the online and in-person surveys suggest that through the images shown in the online survey, consumers could not have perceived all the physical characteristics of the boxes apart from the color of the base/waste materials. Thus, it is hypothesized that the impediment to appreciate paperboard properties could complicate the recognition of the waste, with a more prominent effect on the agricultural waste. For instance, particles of cocoa bean shells in images during the online survey might have been perceived as dark spots on the surface of the material due to the impossibility to recognize the roughness and thickness of the particles. On the other hand, clues such as pieces of waste containing letters or bar codes could have helped the respondents to identify the copy and coated paper as recycled materials. Therefore, the identification of the feedstock could be an important parameter used by the respondents to judge the samples.

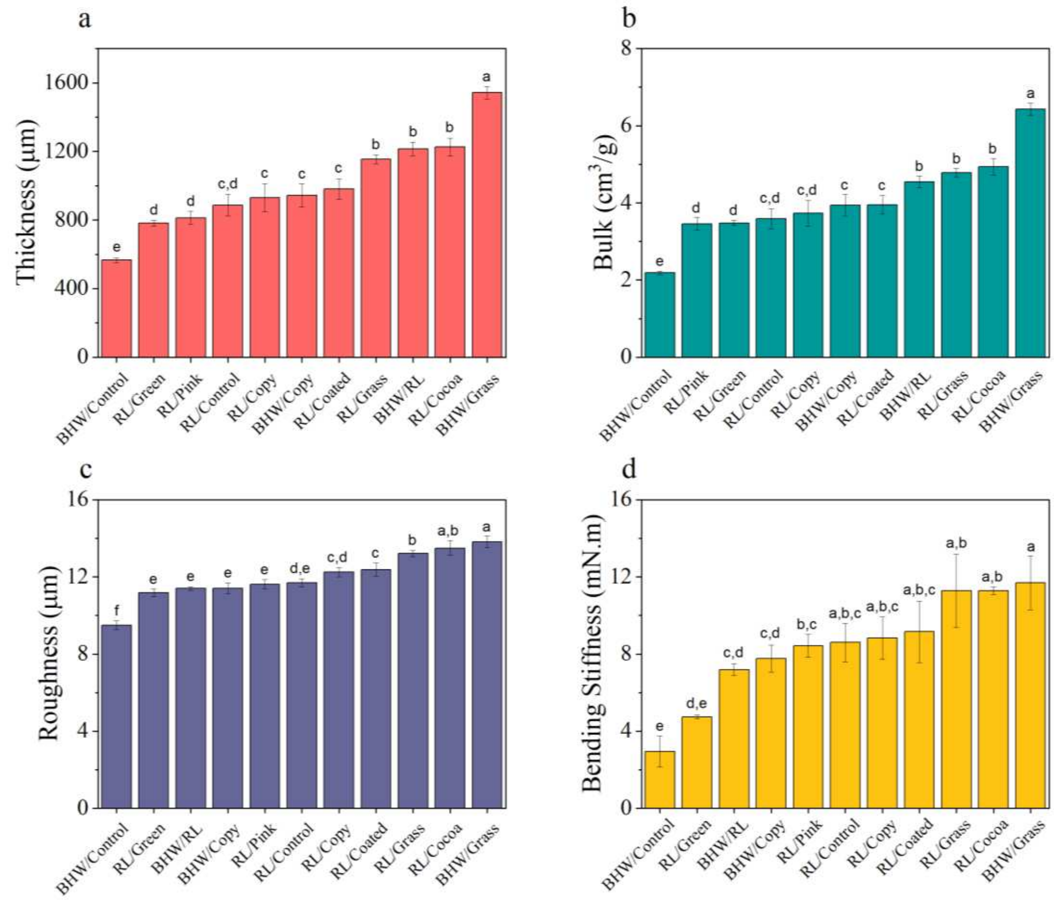

Figure 8. Properties of waste-containing paperboards. (a) Thickness, (b) bulk, (c) bending stiffness, and (d) roughness. Different letters at the top of the bars indicates significant differences between the means ($p < 0.05$).

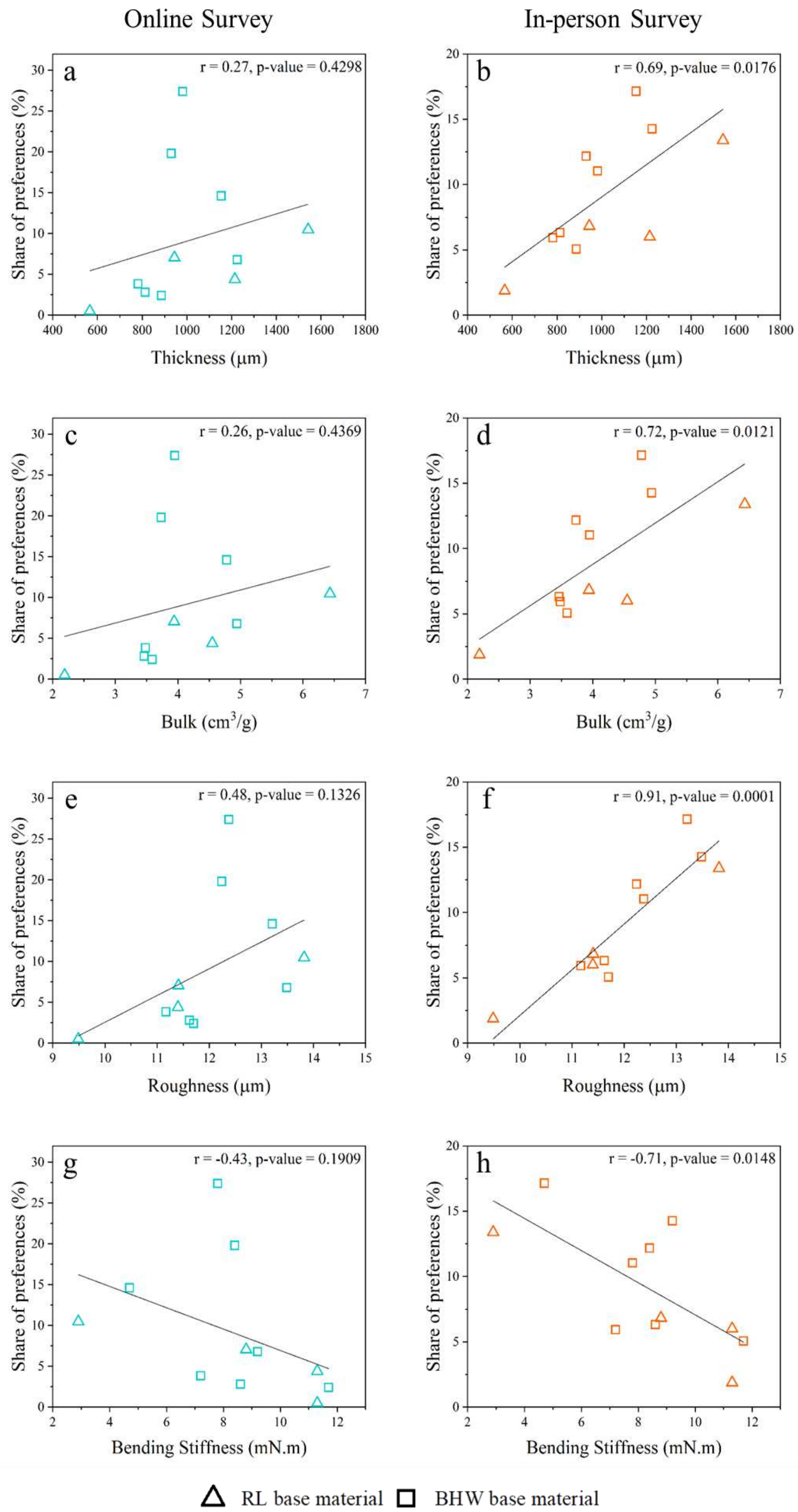

Figure 9. Correlations between share of preferences and paperboard physical properties for online and in person surveys. (a) and (b) thickness, (c) and (d) bulk, (e) and (f) roughness, (g) and (h) bending stiffness. The r values represents the Pearson correlation coefficients.

3.5 Study limitations

The BWS experiments performed in this study enabled the study to address the two main research questions on (1) the relative sustainability perception of visually obvious recovered waste content, and (2) the comparison between online and in-person survey presentation formats. However, BWS experiments only provide a relative measurement, not an absolute one. This means that it can be concluded that paper-based packaging with obvious recovered waste content was perceived as more environmentally friendly than packaging with a clean appearance, but additional information would be needed to anchor the relative scale and gather information on the absolute sustainability perception (Mueller Loose and Lockshin, 2013). In addition, the only criterion that was assessed within this study was the ‘environmental friendliness’. Future research can study additional decision criteria that can influence final consumer preferences, such as ‘perceived toxicity’ or ‘price’.

Given the aim of this study to compare multiple presentation formats (i.e., online and in-person), the geographical spread of the sample was limited to the region of Raleigh, North Carolina. Further research would make it possible to investigate different geographical regions, and focus on, for example, environmental sustainability preferences in a rural context. Also, the in-person surveys were conducted in three different outdoor locations and, as a consequence, the packaging boxes could be affected by conditions such as light intensity, shadow fall, etc. Besides that, the differences between natural lighting (in the in-person survey) and digital imaging (in the online survey) might have partially distorted the perception of color, shape, and size of the particles in the packaging. However, the results herein should give researchers additional incentive to properly select a presentation format which fits the research question, as this might have a significant influence on the study results.

Future research should investigate how the packaging perception would change if different product categories are chosen for the BWS experiment. In the present study, the product that would be inside the packaging box was not specified. Further research can compare, for instance, food and non-food products, and examine if the packaging sustainability perception would change based on what is held in the packaging container. Moreover, other value chain actors such as manufacturers, retailers etc. could be involved to further shape the acceptability and technical feasibility of paper-based packaging containing visually recovered waste.

4. Conclusion

This study aims to understand consumers’ environmental sustainability perception toward redesigned packaging that display visually obvious recovered waste content, and the impact of the study presentation format (online versus in-person) on this packaging perception. A best-worst scaling (BWS) experiment was designed, in which a total, 698 respondents participated (i.e., 487 online responses and 211 in-person responses).

The BWS experiment showed that paper-based packaging with obvious recovered waste content, coming from paper or agricultural waste, was perceived as more environmentally friendly than packaging with a clean appearance (i.e., control samples with no waste). Particles of waste on the surface of the substrates acted as clues of sustainability and guided respondents to make certain judgements on the environmental sustainability of the boxes. From the two base materials used (brown versus white pulp) and the types of waste (paper versus agricultural waste), brown pulp and agricultural waste were perceived as being more environmentally friendly. In addition, it was found that the environmental sustainability perception of certain packages differed between age groups and respondents with a different educational background. Finally, the presentation format (online versus in-person) significantly influenced the choices made by the respondents. Digital photographic images compared to a direct in-person presentation of the real boxes can change respondents’ packaging perception, and should therefore be taken into account when designing surveys. Depending on the goal and resources of a research study, one should opt for a suitable presentation format.

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