

Selection of Environmentally Friendly Material Alternatives to Replace Single-Use Plastics in Cafes and Restaurants Using Multicriteria Analysis Methods: A Case Study of Banda Aceh

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ABSTRAK

Plastik sekali pakai banyak digunakan oleh usaha jasa makanan karena murah, ringan, dan praktis, tetapi masa pakainya yang singkat meningkatkan timbulan sampah persisten. Penelitian ini memeringkat alternatif material untuk kafe dan restoran dengan mengintegrasikan preferensi pemilik bisnis dan konsumen. Survei potong lintang dilaksanakan di Kota Banda Aceh pada Januari-Juni 2025. Sebanyak 24 tempat usaha (12 kafe dan 12 restoran) dipilih dari 568 usaha terdaftar sehingga diperoleh 24 responden pemilik atau pengelola dan 24 konsumen. Keramik, baja nirkarat, kaca, plastik guna ulang, dan bioplastik dievaluasi berdasarkan sembilan kriteria lingkungan, ekonomi, dan sosial menggunakan metode Simple Additive Weighting. Pemilik bisnis menempatkan bioplastik sebagai pilihan utama (20,45), sedangkan konsumen memilih keramik (18,41). Pada hasil gabungan, keramik menempati peringkat pertama dengan skor 36,55 (20,81%), diikuti secara dekat oleh bioplastik sebesar 35,99 (20,49%) dan kaca sebesar 35,91 (20,45%). Jejak karbon rendah menjadi kriteria gabungan paling berpengaruh (13,77%). Selisih skor yang kecil menunjukkan bahwa tidak ada material yang unggul untuk seluruh kondisi: keramik seimbang untuk layanan makan di tempat, sedangkan kaca dan bioplastik terverifikasi dapat melengkapi layanan minuman dan bawa pulang.

Kata kunci: plastik sekali pakai; substitusi material; analisis keputusan multikriteria; Simple Additive Weighting; sektor jasa makanan

ABSTRACT

Single-use plastics are widely used in food-service businesses because they are inexpensive, lightweight, and convenient, but their short service life intensifies persistent waste generation. This study ranked material alternatives for cafes and restaurants by integrating business-owner and consumer preferences. A cross-sectional survey was conducted in Banda Aceh from January to June 2025. Twenty-four establishments (12 cafes and 12 restaurants) were selected from 568 registered businesses, yielding 24 owner or manager responses and 24 consumer responses. Ceramic, stainless steel, glass, reusable plastic, and bioplastic were evaluated using nine environmental, economic, and social criteria and the Simple Additive Weighting method. Owners ranked bioplastic highest (20.45), whereas consumers preferred ceramic (18.41). In the combined assessment, ceramic ranked first at 36.55 (20.81%), followed closely by bioplastic at 35.99 (20.49%) and glass at 35.91 (20.45%). Low carbon footprint was the most influential combined criterion (13.77%). The narrow differences show that no material is universally superior: ceramic is balanced for dine-in service, while glass and verified bioplastic provide complementary options for beverage and takeaway applications.

Keywords: single-use plastic; material substitution; multicriteria decision analysis; Simple Additive Weighting; food-service sector

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INTRODUCTION

Plastic products have become embedded in contemporary food-service systems because they combine low unit cost, low mass, flexibility, and hygienic convenience. These attributes, however, are closely associated with a linear consumption pattern in which packaging and serving items are discarded after only one use. The persistence and fragmentation of plastic waste create long-term exposure pathways for ecosystems and human populations, while inadequate collection and recovery allow discarded plastics to accumulate in terrestrial and aquatic environments (Firmansyah et al., 2021; Jannah et al., 2024). Plastic leakage is therefore not only a waste-management concern but also a broader environmental-governance issue that requires reduction at the source (Hendar et al., 2022).

Cafes and restaurants are relevant intervention points because they routinely distribute cups, straws, bottles, cutlery, plates, bags, and takeaway containers. The frequency of food and beverage transactions can produce a substantial flow of short-lived materials even when the mass of each item is small. Studies of food-service settings in Indonesia have documented intensive use of disposable food and beverage packaging (Priscilla et al., 2020), while consumer experience, visual appeal, convenience, and price continue to influence acceptance of sustainable packaging (Magnier & Schoormans, 2015; Tanzares et al., 2024). Business operators must consequently balance environmental objectives against investment requirements, daily operations, customer expectations, and food-service quality.

Banda Aceh has adopted local waste-generation restrictions through Qanun No. 1 of 2017, including provisions intended to reduce plastic use at commercial sources. Implementation studies nevertheless indicate that regulatory objectives depend on operational adoption by businesses and public participation (Pasya & M. Zuhri, 2024). Community-based initiatives in Banda Aceh further demonstrate that local actors are willing to engage in plastic-waste reduction, but downstream recovery alone cannot substitute for prevention and material reuse (Matanari et al., 2024). Material substitution within cafes and restaurants is therefore a practical pathway for translating local policy into daily business practice.

Choosing a replacement material is not straightforward. Reusable ceramics, stainless steel, and glass may offer long service lives but require capital, washing, storage, handling, and breakage management. Reusable plastic is lightweight and familiar but may retain negative perceptions associated with plastic and chemical safety. Bioplastics may improve the environmental image of takeaway service, yet their performance depends on durability, disposal conditions, supply availability, and cost. Life-cycle studies show that the relative environmental performance of disposable and reusable serviceware is strongly affected by production systems, reuse rates, washing, transport, and end-of-life assumptions (Gallucci et al., 2021; Lewis et al., 2021). Consequently, declaring one material inherently sustainable without considering its use context can be misleading.

Multicriteria decision analysis is suitable for such problems because it makes trade-offs explicit and combines heterogeneous environmental, economic, and social considerations. The Simple Additive Weighting (SAW) method is transparent, computationally simple, and readily interpretable by practitioners: performance values are normalized, multiplied by criterion weights, and summed into an overall preference score (Sudipa & Aryati, 2019). SAW and related multicriteria approaches have been applied to waste-processing selection and sustainable supplier decisions (Chaerul et al., 2020; Stevic et al., 2019). However, previous Indonesian studies have focused mainly on regulation, zero-waste programs, waste-processing systems, or spatial infrastructure choices. Limited evidence is available on material-level substitution in food-service establishments that simultaneously incorporates the views of business owners and consumers.

This study addresses that gap by evaluating five material alternatives for cafes and restaurants in Banda Aceh using paired stakeholder assessments. The objectives were to: (1) identify the criteria that most strongly influence owners and consumers; (2) examine the strongest and weakest attributes of each material; and (3) rank ceramic, stainless steel, glass, reusable plastic, and bioplastic using combined SAW scores. The stakeholder comparison is intended to reveal whether a technically preferred material is also acceptable to the market and operationally feasible for businesses.

METHODS

The study used a cross-sectional, quantitative decision-analysis design and was conducted in Banda Aceh, Indonesia, from January to June 2025. The unit of observation was a cafe or restaurant together with two stakeholder representatives: one business owner or manager and one consumer. The sampling frame contained 568 cafes and restaurants recorded in the city. Sample size was calculated using the non-residential-building sampling approach in SNI 19-3964-1994, producing 23.8 establishments, which was rounded to 24. Random sampling was used to select 12 cafes and 12 restaurants across the city. The paired design generated 24 business-owner responses and 24 consumer responses, for a total of 48 respondents.

Five alternatives were assessed: ceramic, stainless steel, glass, reusable plastic, and bioplastic. These materials represented commonly available pathways for replacing single-use serviceware: durable dine-in items, reusable beverage or food containers, and disposable materials designed with improved environmental attributes. Respondents scored every material against nine criteria on a five-point scale, where 1 indicated very low suitability or importance and 5 indicated very high suitability or importance. The criteria were grouped into three dimensions: environmental, economic, and social. All criteria were formulated as benefit criteria so that higher values represented more desirable performance.

Table 1. Decision criteria and weights used in the SAW assessment

Environmental	Low carbon footprint	Lower climate-related impact across production and use	0.15
Environmental	Low water use	Lower water demand during production, use, and cleaning	0.12
Environmental	High durability	Resistance to damage and longer functional service life	0.11
Economic	Low investment cost	Lower initial cost for purchasing and operational adjustment	0.11
Economic	Low operating cost	Lower daily cost for cleaning, storage, maintenance, and waste handling	0.10
Economic	Low consumer cost	Minimal increase in menu or service price	0.11
Social	Aesthetics	Visual compatibility with the cafe or restaurant setting	0.10
Social	Health	Lower perceived exposure to harmful substances	0.10
Social	Comfort	Ease and convenience of serving, using, and managing the item	0.10

The criterion weights shown in Table 1 sum to 1.00 and were applied consistently to both stakeholder groups. Environmental criteria accounted for 0.38 of the total weight, economic criteria for 0.32, and social criteria for 0.30. The close dimensional weights were intended to prevent the decision from being dominated by a single sustainability pillar while retaining the relatively greater emphasis placed on environmental performance.

For respondent k , alternative i , and criterion j , the raw rating x_{ijk} was normalized by the maximum possible Likert score because all criteria were benefits. The normalized value r_{ijk} and respondent-level SAW score S_{ik} were calculated using Equations (1) and (2). Group preference V_{ig} was obtained by summing respondent-level scores within the business-owner or consumer group, and the final score V_i was the sum of both stakeholder-group scores (Equation 3). This aggregation preserves the equal number of respondents in the two groups and allows direct comparison of owner and consumer priorities.

$$r_{ijk} = x_{ijk} / 5 \quad (1)$$

$$S_{ik} = \sum_j w_j r_{ijk} \quad (2)$$

$$V_i = \sum_k \in \text{owners} S_{ik} + \sum_k \in \text{consumers} S_{ik} \quad (3)$$

Criterion contributions were also summed across alternatives and respondents to identify dominant decision factors. For each material, the criterion with the largest accumulated score was interpreted as its strongest perceived attribute, while the criterion with the smallest score was interpreted as its principal implementation weakness. Results are reported as raw SAW totals and as percentage shares within the relevant stakeholder total. The analysis is descriptive and decision-support oriented; it does not imply statistical significance or causal relationships.

RESULTS AND DISCUSSION

Stakeholder priorities across criteria

The distribution of criterion contributions was relatively balanced, but environmental performance and affordability emerged as the central considerations (Table 2). Low carbon footprint was the largest contribution for business owners (13.24%), consumers (14.34%), and the combined assessment (13.77%). This consistency indicates that both groups associated the transition away from single-use plastics with a visible reduction in environmental impact. It also suggests that environmental claims are likely to influence adoption when they are credible and easy to communicate. Indonesian consumers' sustainable-packaging decisions are shaped by environmental awareness and attitudes, although willingness to pay and practical behavior remain important (Tanzares et al., 2024; Yuliawati et al., 2024).

The second most influential combined criterion was low consumer cost (12.15%). Owners assigned 12.66% of their total criterion contribution to this factor, slightly more than consumers (11.60%). Business operators may anticipate customer resistance when material substitution increases menu prices, deposits, or service charges. This is consistent with evidence that financial and supply-chain barriers affect the replacement of plastic items in cafes and restaurants (Fahmi et al., 2023). The result also reinforces the importance of business models that distribute the cost of durable serveware over many use cycles rather than transferring the initial expense directly to consumers (Purnomo & Munggaran, 2023).

Owners gave greater emphasis than consumers to durability and low investment cost, reflecting concern about replacement frequency and capital exposure. Consumers, by contrast, placed relatively greater emphasis on low water use and comfort. Health had the smallest combined contribution (9.79%), followed by aesthetics (10.29%). These lower shares should not be interpreted as irrelevance; all criteria remained near 10% because of the balanced weighting structure. Rather, they show that respondents treated health and appearance as baseline expectations once functional and environmental requirements were met. The importance of atmosphere and product appearance in cafe behavior has been reported elsewhere, but these qualities alone may not compensate for inconvenience or increased price (Rizqiawan & Novianto, 2023; Magnier & Schoormans, 2015).

Table 2. Contribution of decision criteria by stakeholder group

Criterion	Owners (%)	Consumers (%)	Combined (%)
Low carbon footprint	13.24	14.34	13.77
Low water use	10.58	11.41	10.99
High durability	11.33	10.69	11.02
Low investment cost	11.52	10.75	11.15
Low operating cost	10.23	10.57	10.40
Low consumer cost	12.66	11.60	12.15
Aesthetics	10.58	9.98	10.29
Health	9.55	10.05	9.79
Comfort	10.30	10.60	10.44

Material-specific strengths and weaknesses

Each alternative exhibited a distinct perceived strength and an implementation constraint (Table 3). Ceramic obtained its largest attribute score for low carbon footprint and its smallest for operating cost. Respondents therefore appeared to recognize the repeated-use potential and quality of ceramic, while also acknowledging cleaning, handling, and replacement requirements. Ceramic products can provide a durable dine-in experience and support a premium visual identity; however, the environmental benefit depends on sufficient reuse to offset production and washing impacts. Reusable serviceware assessments similarly show that use intensity and washing systems are decisive parameters (Lewis et al., 2021).

Stainless steel was strongest in durability and weakest in health perception. The material is resistant to breakage and can remain in service for long periods, but consumers may be less familiar with stainless-steel plates, cups, or food containers in some cafe contexts. The low health score is best interpreted as a perception issue rather than evidence of an actual health risk. Clear material specifications, food-grade certification, and communication may therefore be necessary when stainless steel is introduced. Its durability may make it particularly suitable for cutlery, straws, bottles, and high-turnover back-of-house applications.

Glass was valued primarily for its low carbon-footprint potential and was constrained by perceived operating cost. Glass communicates cleanliness, product visibility, and quality, and consumer studies have found favorable perceptions of glass packaging for food and beverages (Taneja et al., 2022). Nevertheless, breakage, transport weight, storage, and washing can increase costs. Life-cycle evidence for glass containers also indicates that recycled content, furnace energy, container mass, and reuse logistics

substantially affect environmental performance (Gallucci et al., 2021). Glass is therefore more defensible for repeated local circulation than for one-way distribution.

Reusable plastic was strongest in low consumer cost but weakest in health perception. Its low mass, resistance to breakage, and low purchase price can facilitate adoption, especially for takeaway systems with deposits or returns. However, the association between plastic and chemical exposure may reduce trust, even when food-grade products are designed for repeated use. Product labeling, replacement schedules, restrictions on heat exposure, and transparent hygiene procedures are necessary to prevent a low-cost option from undermining consumer confidence (Firmansyah et al., 2021).

Bioplastic achieved the highest material-specific score for low carbon footprint but the lowest for durability. Owners may view bioplastic as an operationally simple substitute because it resembles existing disposable items and supports a visible environmental message. However, the label 'bioplastic' covers materials with different feedstocks and end-of-life requirements. Some products require industrial composting and may not degrade effectively in open environments or conventional landfills. Its use should therefore be linked to verified product standards, clear disposal instructions, and an appropriate collection pathway rather than treated as an unconditional solution (Selvamurugan & Sivakumar, 2019).

Table 3. Dominant and weakest perceived criterion for each material

Ceramic	Low carbon footprint (4.92)	Low operating cost (3.60)
Stainless steel	High durability (4.82)	Health (2.96)
Glass	Low carbon footprint (4.71)	Low operating cost (3.50)
Reusable plastic	Low consumer cost (4.62)	Health (2.68)
Bioplastic	Low carbon footprint (5.73)	High durability (2.53)

Stakeholder preferences and final ranking

The stakeholder-specific rankings reveal an important divergence (Table 4 and Figure 1). Business owners selected bioplastic as the leading alternative, with a score of 20.45 and a 22.50% share of the owner total. Ceramic and glass followed with scores of 18.14 and 18.05, respectively. This pattern suggests that owners favored a material that can replace disposables without requiring substantial changes to customer behavior, dishwashing capacity, storage, or item-return systems. The adoption of environmentally framed products can also strengthen business positioning, although green practices are constrained when cost, availability, or supplier reliability are uncertain (Fahmi et al., 2023).

Consumers ranked ceramic first with a score of 18.41 (21.73%), followed by glass at 17.86 (21.08%) and stainless steel at 17.10 (20.18%). Bioplastic ranked last among consumers at 15.54 (18.34%). Consumers thus appeared to prefer familiar, rigid, reusable materials that convey cleanliness, comfort, and product quality. This preference is consistent with the role of tangible service attributes and atmosphere in cafe experience (Rizqiawan & Novianto, 2023). The result also indicates that a material promoted as environmentally innovative may not be accepted automatically if users are uncertain about its functionality or disposal.

The combined ranking placed ceramic first at 36.55 (20.81%), bioplastic second at 35.99 (20.49%), and glass third at 35.91 (20.45%). Stainless steel ranked fourth at 33.73 (19.20%), while reusable plastic ranked fifth at 33.46 (19.05%). The difference between the first- and third-ranked alternatives was only 0.64 points, equivalent to 0.36 percentage points of the combined score. This near-tie is more informative than the ordinal rank alone: ceramic, bioplastic, and glass occupy a common high-preference tier, but they meet different operational needs.

Ceramic provides the strongest compromise for dine-in meals and beverages because it receives high consumer acceptance and remains acceptable to owners. Glass is a complementary option for beverages, desserts, and visible food storage, particularly when breakage control and local reuse are feasible. Bioplastic can serve as a transitional option for takeaway orders or events where recovery of reusable items is impractical, provided that procurement and end-of-life conditions are verified. Stainless steel is strategically useful where durability is critical, even though it may not be the preferred material for every visible customer-facing item. Reusable plastic should be limited to applications where low mass and break resistance clearly outweigh perception concerns and where food-grade management is robust.

These findings support a portfolio strategy rather than a universal material mandate. A restaurant could combine ceramic plates, stainless-steel cutlery, glass drinkware, and certified bioplastic for exceptional takeaway needs. Such functional matching reduces the risk of shifting environmental burdens from plastic waste to excessive washing, breakage, transport, or inappropriate disposal. Multicriteria analysis is valuable in this setting because it makes those trade-offs visible and permits local stakeholders to select combinations that fit service mode and infrastructure (Chaerul et al., 2020).

Table 4. SAW preference scores and combined ranking

Ceramic	18.14	18.41	36.55	20.81	1
Stainless steel	16.63	17.10	33.73	19.20	4
Glass	18.05	17.86	35.91	20.45	3

Reusable plastic	17.62	15.83	33.46	19.05	5
Bioplastic	20.45	15.54	35.99	20.49	2

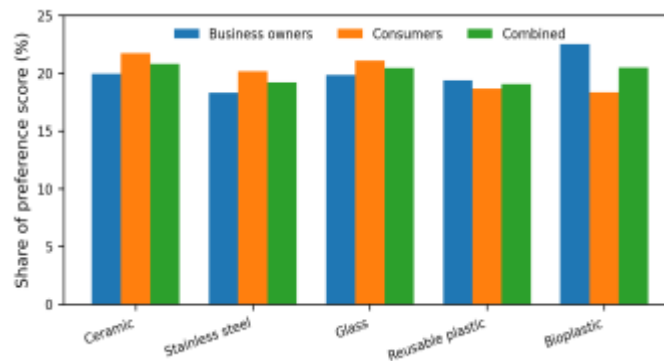


Figure 1. Distribution of material preference scores by stakeholder group

Implementation implications and study limitations

For municipal and business implementation, three measures follow from the results. First, reduction programs should distinguish dine-in and takeaway service. Reusable ceramic, glass, and stainless-steel items are most defensible where repeated circulation can be assured, whereas verified alternatives are needed for residual takeaway demand. Second, procurement decisions should be accompanied by operating protocols for washing, storage, breakage, product retirement, and consumer communication. Third, claims such as biodegradable, compostable, reusable, or low-carbon should be supported by product specifications and by realistic local end-of-life pathways. Environmental labeling without suitable infrastructure may simply relocate the burden.

The study has several limitations. The sample comprised 24 establishments in one city, so the ranking should not be generalized without considering local prices, supply chains, service formats, and consumer cultures. The results are based on stakeholder perceptions rather than direct life-cycle inventory, laboratory testing, or full cost accounting. The predetermined criteria and weights also influence the ranking, and no formal sensitivity or uncertainty analysis was performed. In addition, the alternatives were treated as broad material categories; product thickness, recycled content, manufacturing energy, washing efficiency, and actual reuse cycles can vary widely within each category. Future research should integrate measured environmental and cost data, enlarge the stakeholder sample, conduct sensitivity analysis, and compare SAW results with methods such as AHP, TOPSIS, or PROMETHEE.

CONCLUSION

This study demonstrates that selecting substitutes for single-use plastics in cafes and restaurants is a stakeholder-dependent multicriteria decision. Low carbon footprint was the most influential criterion for business owners and consumers, while affordability—particularly low cost to consumers—was the next major consideration. Business owners preferred bioplastic, whereas consumers preferred ceramic. The combined SAW assessment ranked ceramic first (36.55; 20.81%), followed by bioplastic (35.99; 20.49%) and glass (35.91; 20.45%). Because the top three alternatives were separated by less than 0.4 percentage point, the results should be interpreted as a high-performing cluster rather than proof of an absolute winner. Ceramic is the most balanced option for dine-in service, glass is suitable for repeated beverage applications, and certified bioplastic may complement reusable systems where takeaway or item recovery makes reuse impractical. A context-specific material portfolio, supported by verified environmental claims and operational controls, is more credible than replacing all plastic items with a single material.

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