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PRACTICES AND PERCEPTIONS OF FOOD CONTACT MATERIALS: IMPACT OF EDUCATION IN THE INDIAN CONTEXT

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Abstract

Food contact materials (FCMs) are any substance or article that comes into direct or indirect contact with food during preparation, serving, processing, packaging, transportation or storage. These include materials such as utensils, plastics, glass, disposable materials, parts of equipment, storage tanks, etc. In recent years, these materials have drawn significant interest due to growing concerns over associated health risks. The current evaluations and regulations with respect to kitchen cookware, an important category of FCMs, are inadequate to fully safeguard human health. Additionally, preferences regarding cookware vary widely based on durability, convenience and other factors, making it essential to consider public opinions and usage habits when assessing potential risks. In the present study, for the first time, the effect of education level is evaluated on purchase decisions, standard practices and safety perception regarding different cookware used for food preparation among Indians. The survey data, collected from 227 respondents, revealed that stainless steel was considered the safest kitchen cookware, followed by copper and clay. Significant difference was observed in the safety perception of Teflon, aluminium, cast iron and glass materials ($p<0.05$) with respect to education. While a significant difference was not seen for factors influencing purchase decisions, respondents with higher education levels showed significant awareness about unsafe cookware, leaching of contaminants and their potential health risks ($p<0.05$). However, the findings revealed a gap between awareness and actual practices. Many highly educated individuals continued to use potentially unsafe cookware and failed to replace it over extended periods. These findings suggest that convenience often outweighs safety considerations in everyday decision-making. This highlights the urgent need for improved public education and targeted awareness initiatives to promote safer cookware choices and healthier kitchen practices.

Keywords: Cookware, Education, Food Contact Material, Food safety, Leaching, Toxicity

Introduction

Access to safe and nutritious food is a fundamental determinant of human health. With advancements in food science and technology, it is crucial to ensure food safety within public health and regulatory frameworks. Among the factors influencing food safety, cookware is the most common and highly relevant of all food contact materials (FCMs), owing to its frequent and intense use in both household and commercial settings. Cookware interacts directly with food under various thermal, chemical, and mechanical conditions, potentially contributing to the chemical migration of harmful substances into food, especially when used improperly or over extended periods. A wide array of cookware is used across Indian households, including that made up of aluminium, stainless steel, glass, Teflon, iron and copper. While these materials are valued for their utility, durability, aesthetics and ease of maintenance (Kumar and Joseph 2013; Shamloo et al. 2023), emerging evidence has raised toxicity concerns regarding the leaching of metals (e.g. iron, aluminium, nickel, chromium, lead, zinc, cadmium) and synthetic compounds (e.g. per- and poly-fluoroalkyl substances, phthalates, plasticizers, phenolic derivatives) into food (Carvalho et al. 2022; Fellows et al. 2024; Guarneri et al. 2017; Miralles et al. 2021; Simoneau 2008; Sultan et al. 2023; Yuan et al. 2018). These compounds have been associated with a range of adverse health outcomes, including carcinogenesis, neurotoxicity, endocrine disruption, and organ damage (Patel and Aschner 2021; Sultan et al. 2023). Despite these hazards, awareness concerning the safe use and maintenance of cookware remains limited among consumers, especially in low- and middle-income settings. The absence of reliable sources of collectively organized information further complicates these issues.In India, the issue is compounded by rapidly evolving sociodemographic landscape. There is a significant disparity in literacy between urban and rural populations across different states. A difference in educational attainment has also been noted between males and females (Varughese and Bairagya 2020). Moreover, traditional gender roles are still prevalent, where females bear primary domestic responsibilities, such as cooking and household management (Košir and Lakshminarayanan 2023). With urbanization, there are lifestyle changes, such as a shift to nuclear families, an increasing number of working women and a demand for convenience-oriented consumer goods (Dhillon and Munjal 2022). However, according to national data sources, NFHS-5 and ICMR, a significant rise in non-communicable diseases (NCDs) has been linked to the modern environmental and lifestyle exposures. These NCDs are now the leading cause of deaths and disability in country, accounting for over 5.8 million deaths annually (Anjana et al. 2023; Dolui et al., 2023; Ramesh and Kosalram 2023). Public health interventions have primarily focused on hygiene, foodborne pathogens, and nutritional deficiencies; however, the role of everyday materials, such as cookware, in contributing to chronic exposures has been neglected in public discourse and regulatory action. Although FSSAI regulates

certain aspects of FCMs, the scope of enforcement for cookware materials in domestic use is limited, leaving individuals reliant on brand claims and anecdotal knowledge (Rani et al. 2018).

One of the key determinants that may influence the choice of cookware, awareness of health risks, and adherence to safe practices is education. Education, imparted particularly in growing years, aids in the development of critical thinking, scientific reasoning and rationality among individuals. It forms the foundation of health literacy, which includes the capacity to obtain, process, and understand health information to make appropriate decisions (Brunello et al. 2016; McGaghie et al. 2024; Zimmerman 2007). Literate people are reported to be more aware of the health-related issues, engage in preventive healthcare and make informed decisions regarding nutrition, hygiene, and overall well-being (Donnelly et al., 2024; Fard et al., 2021; Mielck et al. 2013; Onge and Krueger 2011; Petrovici and Ritson 2006; Ruokolainen et al., 2021; Zhang et al, 2021). Conversely, individuals with limited or no formal education often rely on simplified, emotionally driven decision-making and are more susceptible to misinformation and aggressive marketing (Adkins and Ozanne 2005; Stewart and Yap 2020; Viswanathan et al. 2005). Such differences can directly affect cookware choice, safety awareness and practices among individuals, for instance, deciding between stainless steel or non-stick pans, determining whether to discard scratched utensils, and adhering to good maintenance practices. In view of these, it is imperative to expect that educated individuals are more likely to choose safer cooking utensils and be aware of associated health risks owing to exposure to scientific and health-related information, critical evaluation of product claims, and weighing long-term risks and benefits. However, no empirical evidence is present in literature, especially from Indian perspective.

The objective of this study, therefore, is to examine how educational background influences consumers' knowledge, perceptions and practices related to cookware safety in India. This study is the first of its kind in India to explore the intersection of cookware safety, health risk perception and educational background. While purchasing decisions are one component, the study also focuses on risk perception and safe-use behaviors that determine long-term exposure to hazardous compounds from cookware. Although the dataset generated could be utilized to evaluate other objectives, such as the role of gender, family tradition, economic disparity, or food safety awareness in shaping cookware practices, the present study specifically addresses the role of education, given its central importance in fostering health literacy, critical reasoning and informed decision-making in domestic contexts. This focus is particularly relevant in the Indian context, where a wide educational gradient coexists with diverse culinary practices. Understanding how education shapes these everyday domestic decisions can provide

valuable insights can provide valuable insights for public health programming and policy-making. Although limited to commonly used materials and self-reported practices, it provides crucial evidence of the need to set up targeted awareness programs, health initiatives, community outreach, and educational curricula. Ultimately, this research advocates for education-sensitive public health interventions addressing environmental exposures in everyday domestic settings.

Methodology

Data Collection

Data were collected via an online questionnaire created using Google Forms in three languages, English, Hindi and Marathi. The multilingual approach was adopted to minimize language barriers and maximize coverage, thereby improving the accuracy and inclusiveness of responses. The questionnaire was distributed among participants via social media platforms and in-person conversations, targeting adults (18 years and above) who are involved in cooking and actively participate in cookware purchasing decisions. To ensure diverse representation, only one response per household was allowed. A pilot study was run with 40 participants to ensure the clarity and reliability of the responses and to fine-tune the final version of the survey. An in-depth ethical analysis was waived as per the guidelines of the institutional research advisory and ethics committee since the study complied with data protection and ethical principles of the Declaration of Helsinki (updated in 2013), involved anonymous survey responses, and posed minimal risk to participants due to the non-interventional and non-clinical nature of the study. All participants were fully informed about the purpose of the study before completing the questionnaire. They were informed that they would participate in the survey via their devices, that all records would be de-identified, and only aggregated data would be published, maintaining individual privacy/data confidentiality at all times. All participants acknowledged an informed consent statement before participating in the study.

Questionnaire design

The questionnaire was divided into five sections, with a total of 17 items. Section 1 focused on acquiring demographic data such as age, sex assigned at birth, level of education, occupation and family annual income. Section 2 assessed the criteria individuals consider when purchasing cookware. Participants were asked to rate the importance of price, durability, aesthetics, material safety, ease of cleaning, local store availability, and warranty. In Section 3, questions were asked regarding the perceptions of safety with different cookware materials, such as aluminum/anodized aluminum, copper, stainless steel, Teflon, glass, and clay, in everyday cooking. Section 4

explored the frequency of use of these cookware materials for stove-top and oven cooking. Section 5 addressed the awareness of the potential risks associated with cookware materials. Participants were also asked to choose the type of contaminants they are concerned about leaching into food from cookware, with options such as heavy metals, microplastics, carcinogenic substances, hormone-disrupting chemicals, and other forms of chemical leaching. This section also included questions related to common practices among the participants to maintain and use the cookware, such as checking symbols, reading the manufacturer's instructions, frequency of replacing cookware, etc. In some questions, an assessment on a Likert scale was used, with the increasing importance of choice, while other questions required a direct answer, yes or no.

Statistical analysis

Descriptive analysis was carried out by determining frequencies and median for the variables. Non-parametric statistical analyses were performed on the collected data using JASP (0.19.1 version). The Kruskal-Wallis test was used to compare three or more independent groups. In case of significant differences ($p<0.05$) between the groups, Dunn's post hoc test with Bonferroni adjustment was used for pairwise comparison.

Results and discussion

Sociodemographic characteristics of the study sample

The data for this study were collected from Indian adults (18 years and older) who were involved in cooking and actively participated in cookware purchasing decisions. A total of 227 responses were recorded, as shown in Table 1, which were further categorized into three groups based on respondents' highest level of education – (i) SE, school education up to 12th grade, (ii) UG, undergraduate (bachelor's degree and equivalent), and (iii) PG+, postgraduate and above (master's degree, doctorates, etc.).

Table 1 Sociodemographic characteristics of the study sample (n=227)

	Total (n=227)	SE (n=50)	UG (n=93)	PG+ (n=84)
Sex assigned at birth, %				
Female	78.9[a]	92.0	74.2	76.2
Male	21.1	8.0	25.8	23.8
Age, %				
Gen Z (18-27)	33.0	4.0	45.2	36.9
Millennials (28-43)	34.4	34.0	23.7	46.4
Gen X (44-59)	29.9	58.0	29.0	14.3
Babyboomers (≥ 60)	2.7	4.0	2.2	2.4

Occupation, %				
Unemployed	18.1	4.0	25.8	17.9
Homemaker	32.6	76.0	26.7	13.1
Employed	49.3	20.0	47.3	69.0
Annual family income (in lakhs), %				
Less than 3	37.0	60.0	35.5	25.0
Between 3 to 6	23.3	16.0	25.8	25.0
More than 6	39.6	24.0	38.7	50.0

[a]Values in are expressed as percentages.

Respondents were predominantly female (78.9%), reflecting the traditional gender roles associated with cookware usage and household food preparation in many Indian households (Košir and Lakshminarayanan 2023). This trend was especially pronounced in the SE group, where 92% of respondents were female, compared to 74.2% in the UG group and 76.2% in the PG+ group. Age-wise, the sample was balanced, with Gen Z (18–27 years) and Millennials (28–43 years) comprising the majority (33.0% and 34.4%, respectively), followed by Gen X (44–59 years, 29.9%), and a small representation of Baby Boomers (≥60 years, 2.7%). Notably, the SE group skewed older, with 58% belonging to Gen X and only 4% to Gen Z, while the UG and PG+ groups had a higher proportion of younger participants, suggesting a generational shift in education levels. Occupational status varied across education levels. While nearly half of the total sample was employed (49.3%), the SE group had the lowest employment rate (20%) and the highest percentage of homemakers (76%), emphasizing their central role in day-to-day cookware use despite limited formal education. In contrast, the PG+ group reported the highest employment rate (69%) and the lowest percentage of homemakers (13.1%), indicating increased workforce participation and potential exposure to a broader range of information sources. The annual family income also demonstrated a clear upward trend with increasing education. While 60% of the SE group reported an annual income of less than 3 lakhs, only 24% of PG+ participants fell into this bracket. Conversely, 50% of the PG+ group reported incomes exceeding six lakhs annually, compared to just 24% in the SE group. This financial stratification underscores the intersection of education, occupation, and income, all of which can influence awareness, access, and adoption of safe food contact materials.

Factors affecting the purchase of cookware

Purchase behaviour depends on both market-dominated variables (such as brand and advertising) and consumer-dominated variables, including gender, needs, awareness, perception, disposable income, personality, family traditions, and innovative technological designs (Hammar et al. 2007; Kumar and Joseph 2013; Merwe and Campbell 2008). Similar to Portuguese people, where safety, convenience and durability are reported to be the key

factors shaping cookware choice (Moura et al. 2023), our study sample also exhibited durability (93%), material safety (92%) and ease of cleaning (86%) as important criteria influencing cookware purchase (Figure 1).

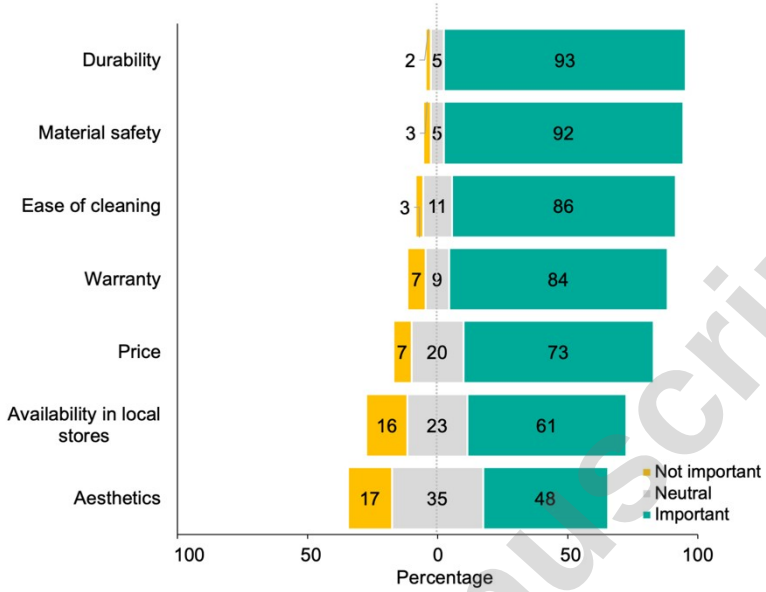

Fig.1 Key factors influencing cookware purchase among the participants

A similarly high level of importance was observed for warranty (84%), indicating that participants value not only product quality and safety but also post-purchase assurance. In contrast, fewer respondents considered price (73%), availability in local stores (61%), and aesthetics (48%) to be critical. Notably, a substantial proportion of participants viewed aesthetics as either neutral (35%) or not important (17%), highlighting a strong preference for utilitarian features over visual appeal in cookware selection.

To further explore whether these preferences varied by educational attainment, the responses were analyzed using the Kruskal-Wallis test (Table 2). The median score for the majority of attributes was 3, indicating that participants rated most attributes as important, regardless of their level of education. Durability and material safety were rated as important by over 90% of respondents, with no statistically significant differences between the groups ($p = 0.664$ and 0.883, respectively). Similar patterns were observed for ease of cleaning and warranty, with over 80% of each subgroup rating them as important. No significant differences were found ($p = 0.896$ and 0.825), indicating uniform expectations for ease of maintenance and after-sales assurance.

Table 2 Analysis of factors influencing cookware purchase with respect to education

	Median (n = 227)	SE (n=50)			UG (n=93)			PG+ (n=84)			p-value[c]
		1[a]	2	3	1	2	3	1	2	3	
Durability	3	2.0[b]	8.0	90.0	2.2	4.3	93.5	2.4	3.6	94.0	0.664
Material safety	3	4.0	4.0	92.0	2.1	5.4	92.5	3.6	5.9	90.5	0.883
Ease of cleaning	3	2.0	14.0	84.0	3.2	9.7	87.1	3.6	10.7	85.7	0.896
Warranty	3	8.0	6.0	86.0	5.4	9.7	84.9	7.2	10.7	82.1	0.825
Price	3	8.0	16.0	76.0	5.4	24.7	69.9	9.5	16.7	73.8	0.817
Store availability	3	18.0	26.0	56.0	11.8	26.9	61.3	19.0	16.7	64.3	0.706
Aesthetics	2	20.0	32.0	48.0	21.5	35.5	43.0	9.5	35.7	54.8	0.129

[a]3-point rating scale: 1-Not important; 2-Neutral; 3-Important.
[b]Values in education categories are expressed as percentages.
[c]p-value for comparisons between the groups determined using the Kruskal-Wallis test.

Although price is often considered a key determinant in consumer decision-making, only 69.9% of respondents in PG+ considered it important, compared to 76% in SE group. While this may indicate that higher-educated individuals are somewhat less price-sensitive, the difference was not statistically significant ($p = 0.817$). Similarly, availability in local stores showed a modest increase in importance among PG+ (64.3%) compared to SE individuals (56%), but this variation was also not significant ($p = 0.706$). Aesthetics was the only attribute that showed a noticeable shift across education levels, with the importance rating rising from 48% in the SE group to 54.8% in the PG+ group. Despite this pattern implying that highly educated people might give slightly more weight to appearance and design, the difference was not statistically significant ($p = 0.129$). Overall, our data showed that participants tend to prioritize the practicality and functionality of cookware over its appearance, and that the level of education does not influence their purchase decisions. These findings align with the value-seeking and comparison-shopping behaviour commonly observed among Indian consumers (Pabalkar 2024). Due to this

tendency, Indians, regardless of their level of education, are often seen to purchase high-quality products at affordable prices, focusing on brands and features (Devi et al. 2022).

According to the report of the World Bank (2024), the purchasing power of the Indian middle class has increased in recent years. However, a significant portion of the population still faces affordability concerns. Hence, we also examined whether the income levels of respondents affect the purchase decisions regarding kitchenware. Here also, durability and price emerged as the two most important factors; however, no significant difference was found in the consumer behaviour. This trend suggests that people often compensate for a higher price with the perceived durability of goods. In the long term, this approach reduces their expenses and makes cookware like stainless steel acceptable in homes, even with modest means.

Safety perceptions of the cookware

Consumers have access to a variety of cookware types, each offering specific benefits that influence purchasing decisions. Copper and iron cookware have held a very significant place in the Indian household for centuries. Cooking food and storing water in these utensils provides the dietary intake of copper and iron via leaching, thereby improving bone health, neurological function, iron metabolism and hemoglobin content (Alves et al., 2019; Saxena et al., 2021). Modern kitchenware like stainless steel is durable, corrosion-resistant and widely considered safe for everyday use. Aluminium is lightweight, inexpensive and conducts heat efficiently. Teflon-coated non-stick pans reduce the need for oil and are easy to clean (Pati et al., 2024). Glass and ceramic cookware are chemically inert, provide even heating and are aesthetically appealing, while clay pots are traditional, affordable and impart distinctive flavor to food (Aderemi et al., 2017).

However, scientific studies highlight that many of these materials also possess safety concerns due to the transfer of contaminants (metals or chemical residues) through leaching or migration. The factors affecting this transfer are temperature, acidity or alkalinity of the food, cooking duration and quality of the kitchenware (Alabi et al. 2020; Koo et al. 2020; Sultan et al. 2023). Moreover, most modern kitchen utensils are made from alloys rather than a single material, which increases the variety and complexity of metals or chemicals that may leach into food. Koo et al. (2020) reported the leaching of toxic metals from everyday kitchen utensils made of stainless steel, copper alloy, aluminium alloy and cast iron. Under acidic conditions, stainless steel cookware was found to leach the highest amount of chromium (~240 µg/L), followed by nickel (28 µg/L). Aluminium alloy cookware also showed

release of chromium (38 µg/L) and nickel (317 µg/L). In copper alloy cookware, lead leaching was predominant at 227 µg/L. Release of nickel and chromium in the range of 15–19 µg/L and arsenic at 6 µg/L was also reported. The cast iron exhibited the highest overall release, with chromium reaching 2000 µg/L, arsenic 27 µg/L, lead 25 µg/L, and an exceptionally high nickel concentration of 25,000 µg/L. Similar observations of metal leaching from stainless steel, aluminium and copper cookware have been reported by multiple studies (Guarneri et al. 2017; Hedberg and Wallinder 2016; Herting et al. 2008; Kuligowski and Halperin 1992; Sultan et al. 2023). In a different study, Koontz et al. (2022) evaluated the release of copper from lined and unlined copperware under acidic conditions. In lined cookware, ~400 µg copper was released from a contact area of 150 cm^2 in 3 h. However, the amount of leaching was significantly higher in unlined copperware, where ~10000 µg of copper leaching was reported.

In India, FSSAI regulates metal contaminants by setting maximum limits according to the type of food commodity. The Council of Europe has established the specific release limits of 4, 0.25, 0.14, 0.002 and 0.01 mg/kg for copper, chromium, nickel, arsenic and lead, respectively, for FCMs (CoE, 2013). However, several studies have reported metal leachate levels exceeding these limits, highlighting a significant public health concern. Chromium, arsenic, lead and nickel have also been categorized as group 1 carcinogens by the International Agency for Research on Cancer (IARC, 2012). Exposure to these metals has been demonstrated to disrupt the expression of tumor suppressor genes and inhibit DNA repair mechanisms (Bánfalvi, 2011). In addition, nickel exposure has also been associated with kidney disease, allergies and systemic dermatitis, particularly in nickel-sensitve individuals (Silverberg et al., 2020). Copper toxicity is relatively uncommon under daily life conditions; however, copper toxicity can lead to severe liver damage (cirrhosis) due to copper-induced oxidative damage, as prominently seen in Wilson's disease among humans (de Romaña et al., 2011). In animals, excessive intake of copper has been reported to cause hematological and hemorheological changes affecting both the protein content of the erythrocyte membrane and heme synthesis (Özçelik et al., 2002). Since manufacturers do not always specify the grade, quality, lining material or composition of utensils, and consumers are generally unaware of what to look for on such labels, the risk of excessive exposure can become a serious concern.

Non-stick cookware, coated with chemicals like Teflon and perfluorooctanoic acid (PFOA), poses risks when overheated beyond ~260 °C. The Teflon coatings degrade at such a high temperature and release toxic fumes containing chlorofluorocarbons, leading to 'Teflon flu' (Pati et al., 2024). Scratched non-stick coatings may also

expose underlying metals (Bansal et al. 2020). Moreover, PFOA has recently been moved from Group 2B (possible carcinogen) to Group 1 (carcinogenic to humans) due to sufficient evidence for cancer in experimental animals and "strong" mechanistic evidence in exposed humans (IARC, 2023). Ceramic cookware may leach lead, arsenic or cadmium if overglazed with heavy metals, as reported in Nigeria (Aderemi et al., 2017). In contrast, unglazed ceramic, glass and clay cookware have not been associated with chemical leaching and, thus, they appear to be the safest options available in the market for food preparation, provided they are manufactured from safe and uncontaminated raw materials.

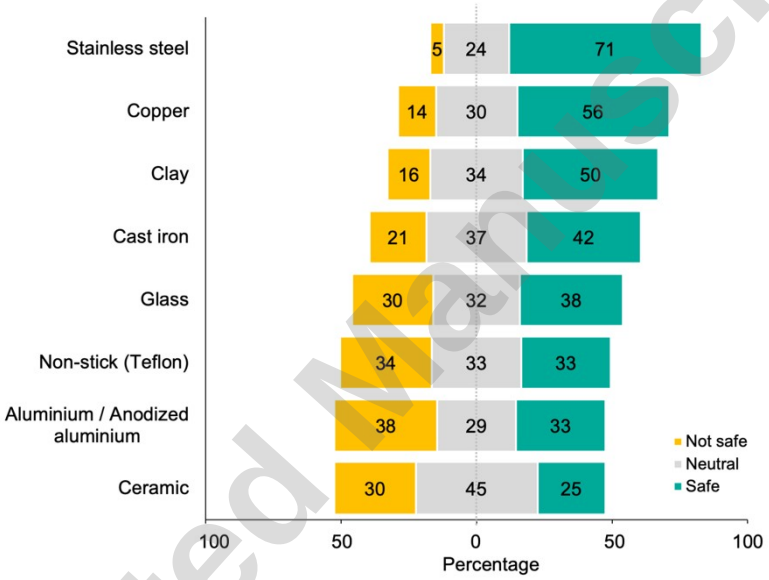

Fig.2 Safety perception of different cookware in the study sample

While consumers are attracted to cookware for its functional and cultural benefits, they may be unaware of the hidden hazards. Evaluating safety perception is essential as it strongly influences consumer choices and market trends. Figure 2 illustrates the overall safety perception of different cookware materials. Stainless steel was regarded as safest (71%) followed by copper (56%) and clay (50%). Conversely, ceramic cookware was considered safe by only 25% of respondents, while aluminium, non-stick (Teflon), and glass also received lower safety ratings (33%–38%). This distribution suggests a clear bias toward traditionally accepted and widely used materials such as stainless steel. Table 3 provides a detailed analysis of how education level influences safety perceptions of different cookware types. Significant differences ($p < 0.05$) in safety perception have been observed for cast iron ($p = 0.033$), glass ($p < 0.001$), non-stick (Teflon) ($p < 0.001$), aluminium ($p = 0.004$), and ceramic ($p = 0.010$). Specifically, PG+ respondents rated glass, cast iron, and ceramic as safer than SE and UG groups. While

only 20% of SE participants considered glass cookware safe, this proportion increased to 52.4% among PG+ respondents. Similarly, non-stick cookware was considered safe by 56% of SE, but only 27.4% of PG+ deemed it safe.

Table 3 Safety perception of different cookware with respect to education

	Median (n = 227)	SE (n=50)			UG (n=93)			PG+ (n=84)			p-value[c]
		1[a]	2	3	1	2	3	1	2	3	
Stainless steel	3	12.0[b]	22.0	66.0	3.2	32.3	64.5	3.5	16.7	79.8	0.066
Copper	3	12.0	36.0	52.0	14.0	21.5	64.5	15.5	34.5	50.0	0.216
Clay	3	24.0	34.0	42.0	16.1	37.6	46.3	11.9	29.8	58.3	0.089
Cast iron	2	28.0	38.0	34.0	23.7	38.7	37.6	14.3	33.3	52.4	0.033
Glass	2	46.0	34.0	20.0	31.2	33.3	35.5	19.0	28.6	52.4	< 0.001
Non-stick (Teflon)	2	18.0	26.0	56.0	35.5	37.6	26.9	41.7	30.9	27.4	< 0.001
Aluminium	2	26.0	18.0	56.0	40.9	32.2	26.9	41.7	33.3	25.0	0.004
Ceramic	2	42.0	46.0	12.0	27.9	49.5	22.6	25.0	39.3	35.7	0.010

[a]3-point rating scale: 1-Not safe; 2-Neutral; 3-Safe.
[b]Values in education categories are expressed as percentages.
[c]p-value for comparisons between the groups determined using the Kruskal-Wallis test.

Pairwise comparison, shown in Figure 3, further highlights the significant differences in perceived safety between the SE and PG+ groups using Dunn's post-hoc test. For aluminium, significant differences were found between SE and UG ($p < 0.05$) and SE and PG+ ($p < 0.01$), with the PG+ group rating it least safe. A similar trend was observed for non-stick cookware, with PG+ participants expressing significantly lower safety ratings than both SE and UG groups ($p < 0.01$). Despite the numerous reports on the toxicity of aluminium and non-stick cookware (Alabi and Adeoluwa 2020; Bradley et al. 2007; Sajid and Ilyas 2017; Sultan et al. 2023), more than half of SE respondents considered them safe while the number is half of that in UG and PG+ groups, reflecting a greater caution among more educated individuals. This pattern was reversed for glass and ceramic cookware, where the majority of SE respondents considered them unsafe for cooking. However, glass and unglazed ceramic are indeed food-safe materials owing to lower chemical complexity resulting in lower chemical migration (Geueke et al. 2014). This

indicates that people with a higher education level have better perception of cookware safety owing to more exposure and knowledge.

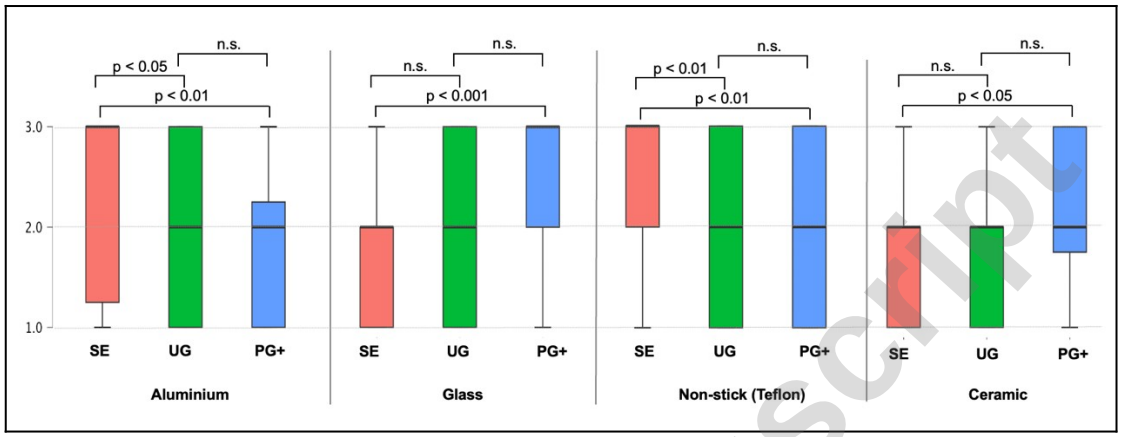

Fig.3 Pairwise comparison of perceived safety in education groups. 3-point rating scale: 1-Not safe; 2-Neutral; 3-Safe. p-values determined using Dunn's post-hoc test (with Bonferroni adjustment)

Frequency of usage

Figure 4 illustrates the overall frequency of usage of different cookware materials among participants. Stainless steel emerged as the most frequently used material, with 67% of respondents reporting "often" and 22% "sometimes" usage. Non-stick (Teflon) and aluminium/anodized aluminium cookware were also commonly used, with 33–38% reporting frequent use. In contrast, traditional materials such as clay and ceramic were found to be the least used cookware. Over half of the respondents (56% and 55%, respectively) reported never using them. Glass and copper cookware were also relatively less popular, with 43% and 38% reporting no usage.

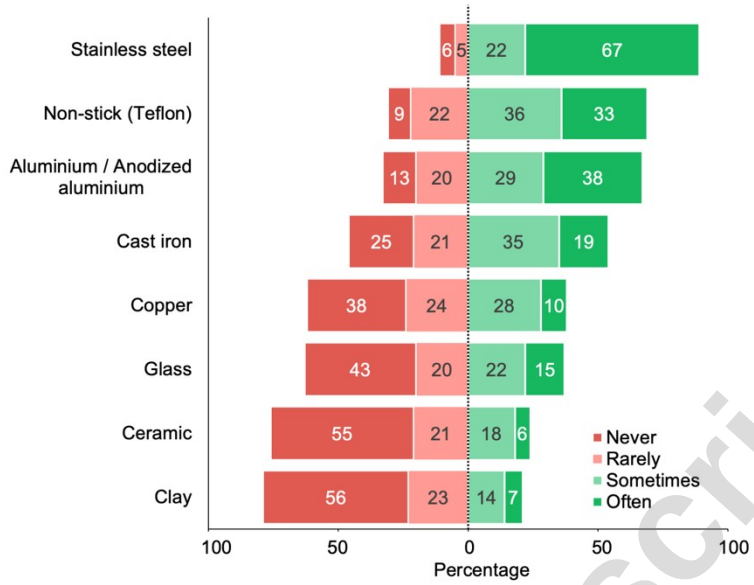

Fig.4 Frequency of usage of different cookware in the study sample

Table 4 reveals statistically significant differences in the usage of aluminium (p = 0.021), cast iron (p = 0.005), and glass cookware (p = 0.005) across educational groups, as determined by the Kruskal–Wallis test. PG+ participants reported more frequent usage of aluminium (39.3%) and glass (30.9%) compared to SE and UG groups. Notably, cast iron was more commonly used among PG+ individuals (44.1% "sometimes"), while 38% of the SE group reported never using it. While stainless steel is considered safe and hence widely used across all education groups with no significant difference (p = 0.619), research has highlighted the potential adverse effects associated with excessive exposure to nickel and chromium (Silverberg et al., 2020). However, this information is still confined mainly to the domain of scientific research and is not commonly known among the general public, particularly in the context of metal leaching from stainless steel cookware. Consequently, a cautious approach is warranted, especially among sensitive individuals. The usage frequency of other cookware was also observed to be reasonably similar across education groups (p > 0.05).

Table 4 Usage frequency of different cookware.

	Median (n = 227)	SE (n=50)				UG (n=93)				PG+ (n=84)				p-value[c]
		1[a]	2	3	4	1	2	3	4	1	2	3	4	
Stainless steel	4	8.0[b]	8.0	20.0	64.0	6.4	4.3	23.7	65.6	4.8	3.6	21.4	70.2	0.619

Non-stick (Teflon)	3	10.0	16.0	36.0	38.0	8.6	21.5	37.6	32.3	8.3	26.2	34.5	31.0	0.638
Aluminium	3	12.0	18.0	18.0	52.0	15.0	29.0	28.0	28.0	13.1	10.7	36.9	39.3	0.021
Cast iron	3	38.0	22.0	28.0	12.0	26.9	23.7	30.1	19.3	14.3	19.0	44.1	22.6	0.005
Copper	2	38.0	24.0	30.0	8.0	40.9	19.3	24.7	15.1	35.7	27.4	30.9	6.0	0.970
Glass	2	60.0	22.0	8.0	10.0	43.0	15.1	25.8	16.1	30.9	25.0	27.4	16.7	0.005
Ceramic	1	60.0	26.0	10.0	4.0	53.8	22.5	18.3	5.4	54.8	15.5	21.4	8.3	0.478
Clay	1	52.0	26.0	10.0	12.0	61.3	19.3	14.0	5.4	52.4	25.0	16.7	5.9	0.447

[a]4-point rating scale: 1-Never; 2-Rarely; 3-Sometimes; 4-Often.
[b]Values in education categories are expressed as percentages.
[c]p-value for comparisons between the groups determined using the Kruskal-Wallis test.

Pairwise comparisons for these cookware materials revealed a significant difference in usage frequency between the SE and PG+ groups (Figure 5). The SE group used aluminium more frequently for food preparation compared to the PG+ group ($p<0.05$), while the reverse pattern was observed for glass and cast iron ($p<0.01$). Safety perception associated with cookware, as mentioned in the previous section, is the plausible explanation for this observation. However, the significant difference seen regarding the safety perception of non-stick cookware was not translated into practice. It was shown that a substantial proportion of PG+ participants reported Teflon as unsafe. Despite this, their frequency of usage of non-stick cookware is comparable to that of the SE group. It has been highlighted that health-conscious people prefer cookware that facilitates cooking with little to no oil, making non-stick material a popular choice (Luo et al. 2002). Moreover, individuals are also looking for easy-to-clean cooking solutions. This indicates that even educated consumers often prioritize convenience over safety. It is important to note that this is the first study to demonstrate the discord between the level of education and safe cookware practices. A similar pattern regarding dietary behaviour has also been observed by Liguori et al. (2022) where consumers, despite having knowledge of food safety, fail to avoid unsafe food.

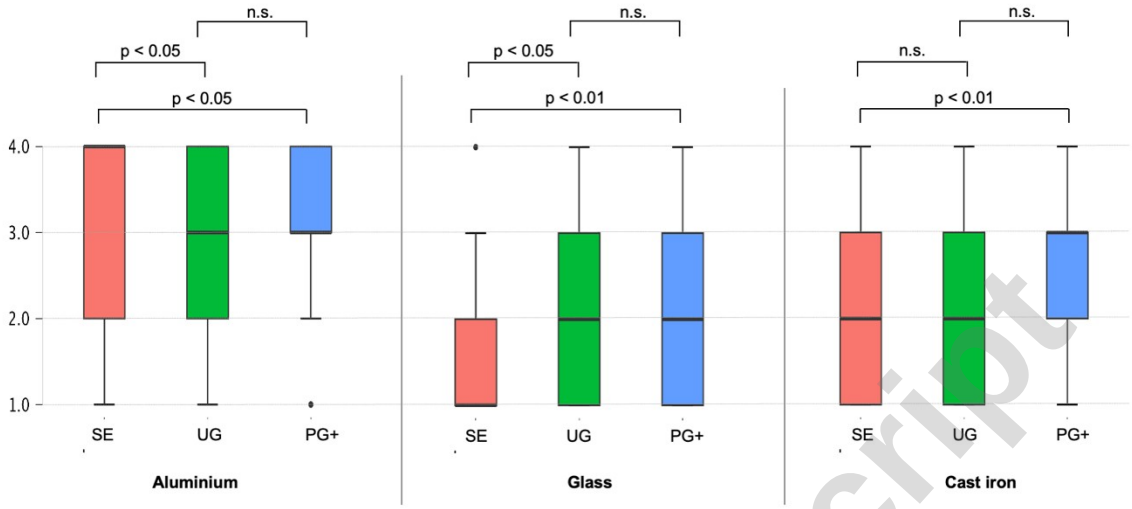

Fig.5 Pairwise comparison of usage frequency in education groups. 4-point rating scale: 1-Never; 2-Rarely; 3-Sometime; 4-Often. p-values determined using Dunn's post-hoc test (with Bonferroni adjustment)

Awareness and common practices

Microwave ovens are indispensable in the kitchen today owing to their ability to reheat or cook food within minutes. Its penetrance has also been boosted in Indian homes due to the increasing number of working women and nuclear families. Despite this fact, only 40% of the total respondents were able to recognize the microwave-safe symbols correctly. However, the number is significantly higher among PG+ groups as compared to the other two groups, reflecting increased exposure due to education. These observations are comparable to the findings of Martins et al. (2022) in a cross-cultural study between Brazil and Portugal. Shollapur and Anitha (2007) report shallow awareness about microwave ovens among Indian consumers. A similar pattern is also seen in the Malaysian population (New et al. 2017). This indicates the need for educational programs on microwave safety knowledge to be disseminated in public.

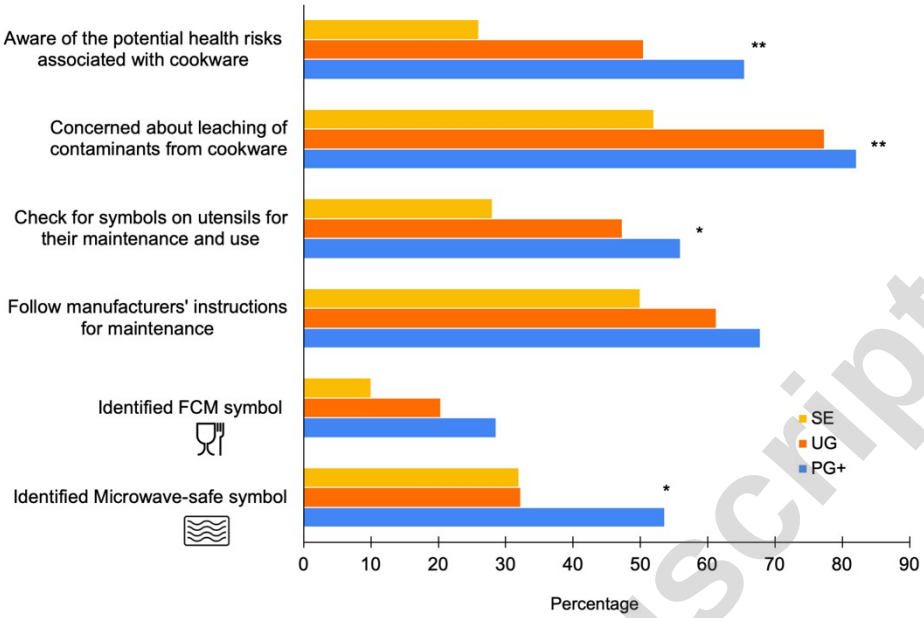

Fig.6 Evaluation of awareness, knowledge and practices among participants. Statistical difference between education groups analyzed by Kruskal-Wallis test. (* $p < 0.05$, **$p < 0.001$)

Regarding the FCM symbol, very few participants (21.1%), particularly from SE groups, could correctly identify the symbol, as illustrated in Figure 6. The number obtained is much less compared to Portuguese individuals, where 52.3% of the participants can recognize the symbol (Moura et al. 2023), indicating the deficit in awareness and knowledge among Indians.

While 73.6% of the survey sample reported having concerns about leaching of contaminants, particularly carcinogens and heavy metals, only 51% were aware of the different health risks associated with cookware (Figure 6). Respondents cited Google, social media, books and newspapers as the primary source of information. Few respondents also mentioned receiving information through family/relatives and scientific communications. Despite the reports on the leaching of toxic chemicals, cancer-causing substances, heavy metals, and hormone-disrupting contaminants (Cwiek-Ludwicka 2015; Paula and Alves 2024; Shamloo et al. 2023; Sultan et al. 2023; Topanci et al. 2022), a significant lack of awareness and concern about health risks and cookware safety was observed in SE group in comparison to UG and PG+ groups. A similar observation was also made by Saxena et al. (2022), where 61.9% of Indian participants were reported to be unaware of the leaching of per- and poly-fluoroalkyl substances during cooking.

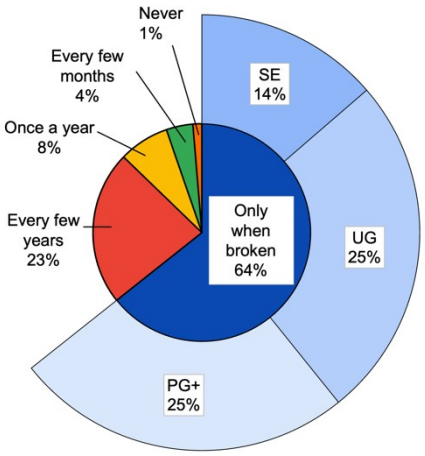

Fig.7 Assessment of replacement of cookware

Culinary factors such as pH, salinity, time, temperature, and process of cooking have been reported to affect the level of leaching and corrosion of cookware (Alabi et al. 2020; Alabi and Adeoluwa 2020; Al Zubaidy et al. 2011). Besides these, material, lifespan and quality of cookware, frequency and duration of use, washing and maintenance conditions are also important in preventing the migration of contaminants (Alabi et al. 2020; Koo et al. 2020; Sultan et al. 2023). In our study, PG+ respondents demonstrated to adopt better practices, such as checking symbols and following manufacturers' instructions for maintenance and use of the utensils (Figure 6). However, the difference is not significant when it comes to replacement of cookware. Overall, 64% of the respondents agreed to replace their cookware only when broken (Figure 7). In a survey pertaining to homemakers in the Patna region (India), 66% were reported to replace their utensils after breakage (Sharma et al. 2021). This reflects the behaviour of value-conscious consumers who tend to use cookware beyond its safety lifespan, often at the expense of health. Traditions also play a significant role in the Indian household, where kitchenware is expected to last decades and sometimes even be passed down across generations (Kaur et al. 2022). Examples include soapstone, cast iron pans (tawa) and copperware pots. Such deeply embedded practices are challenging to change; however, it is not impossible. Stainless steel made its way to typical households, replacing then-existing bronze utensils, owing to affordability, durability and ease of maintenance (Wood 2002). This shift illustrates that consumer habits can evolve when safer or more convenient alternatives are introduced. Regarding the interest in obtaining more information about food-safe materials, the majority of participants (89.4%) answered that they

were interested in increasing their knowledge and awareness (data not shown), implying their readiness for guidance that could help them make safer and more informed choices in selecting and using the cookware.

Conclusions

In the present study, for the first time, the role of education in shaping consumer behavior regarding purchase, risk perception and knowledge about materials of cooking utensils has been evaluated. The findings of our study clearly indicate that durability and material safety are prioritized across all education groups when selecting cookware. Notably, stainless steel emerged as the most trusted and frequently used material, reflecting its reputation for safety, longevity, and familiarity among Indians. However, the reports on nickel and chromium leaching are worrisome. Therefore, consumers should exercise caution when using and maintaining stainless steel cookware. While education level appears to enhance awareness and general understanding of material safety, it does not necessarily translate into informed practices. This disconnection between what individuals know and how they act is particularly evident in their safety perceptions, usage patterns, and daily habits related to cookware selection, maintenance and replacement. Moreover, the study sheds light on the lack of knowledge regarding food-safe materials, when to replace them and the potential long-term health risks of continued use of degraded or unsafe materials. This gap in understanding has implications for public health and consumer well-being. These insights reflect an urgent need for education and awareness initiatives for people in India. Therefore, government agencies should support research in the area of cookware toxicity and development of safer, durable and affordable cookware alternatives. This reliable, accessible and scientifically backed information sources can guide consumers in making safe and sustainable cookware choices. A change can also be fostered through the implementation of supportive policies and safety standards. Marketing strategies, such as advertisements and celebrity endorsements linking safe cookware with modern lifestyles, health benefits and cultural values, could further accelerate this transition. Ultimately, empowering consumers with the proper knowledge can bridge the gap between awareness and practice, leading to safer kitchen environments and better health outcomes.

Declarations

Competing interest: The authors have no competing interests to declare that are relevant to the content of this article.

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