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HOUSEHOLD WASTE GENERATION IN BUENOS AIRES, ARGENTINA: IMPACT OF COVID-19 LOCKDOWNS

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ABSTRACT

The COVID-19 pandemic lockdown reshaped household routines worldwide, influencing both the quantity and composition of municipal solid waste. In Argentina, lockdowns in 2020-2021 restricted mobility, with mandatory stay-at-home orders and suspension of most non-essential commercial and institutional activities. This study analyzed household waste generation in Ciudad Autónoma de Buenos Aires (CABA), Argentina, across three distinct periods: before (March 2019 to March 2020), during (March 2020 to October 2021), and after lockdown (November 2021 to November 2022). A citizen science approach was employed, engaging non-specialist residents in data collection through researcher-designed protocols. A total of 828 households voluntarily participated by sorting and weighing their waste over a one-week period, classifying it into five categories: (i) organic (*i.e.* biodegradable), (ii) plastic, (iii) paper and cardboard, (iv) other recyclables, and (v) non-recyclable (*i.e.* residual waste). Data were submitted via an online platform. Results showed a significant increase in the generation of non-recyclables during lockdowns, followed by a rise in recyclable materials —paper and cardboard, and plastic— after lockdowns. Total and organic waste generation remained invariable throughout the study period. After lockdowns, waste generation averaged 447±298 g person^{-1} d^{-1}. Waste composition exhibited modest variations throughout the study period comprising 42% organic, 33% recyclables and 25% non-recyclable waste after lockdowns. The pandemic altered certain household behaviors, which in turn affected waste generation patterns and composition in CABA. Citizen science once again demonstrated its effectiveness in capturing these temporal trends.

Key words: citizen science, lockdown, pandemic, pets, waste composition.

GENERACIÓN DE RESIDUOS DOMICILIARIOS EN BUENOS AIRES, ARGENTINA: IMPACTO DEL CONFINAMIENTO POR COVID-19

RESUMEN

Los confinamientos por la pandemia de COVID-19 modificaron las rutinas domésticas, afectando tanto la cantidad como la composición de los residuos domiciliarios. En Argentina, los confinamientos restringieron la movilidad, suspendiéndose las actividades comerciales e institucionales. Se analizó la generación de residuos domiciliarios en la Ciudad Autónoma de Buenos Aires (CABA), Argentina, en tres períodos: antes (marzo 2019-marzo 2020), durante (marzo 2020-octubre 2021) y después del confinamiento (noviembre 2021-noviembre 2022). Se empleó un enfoque de ciencia ciudadana que involucró a residentes no especializados en la recolección de datos siguiendo protocolos diseñados por investigadores. Un total de 828 hogares voluntarios clasificaron y pesaron sus residuos durante una semana, en cinco categorías: (i) orgánicos (biodegradables), (ii) plásticos, (iii) papel y cartón, (iv) otros reciclables y (v) no reciclables (resto). Los datos fueron enviados a través de una plataforma en línea. Durante el confinamiento aumentó significativamente la generación de residuos no reciclables y, tras este, aumentó la de reciclables (papel, cartón y plástico). La generación total y de residuos orgánicos se mantuvo estable. La composición de los residuos sufrió cambios modestos a lo largo del periodo analizado. Luego del confinamiento, la generación promedio de residuos fue de 447±298 g persona^{-1} día^{-1} y su composición fue 42% orgánicos, 33% reciclables y 25% no reciclables. Los patrones de generación y composición de residuos en CABA cambiaron respecto al periodo previo a la pandemia y podrían relacionarse a la modificación de ciertos hábitos domésticos. La ciencia ciudadana demostró nuevamente su eficacia para captar estas tendencias temporales.

Palabras clave: composición de residuos domiciliarios, ciencia ciudadana, pandemia, aislamiento, mascotas.

INTRODUCTION

The COVID-19 pandemic triggered lockdowns worldwide, which dramatically modified people's routines, including waste generation and management. Most people stopped working and consuming outdoors and spent more time at home. Waste generation dynamics changed, however, there was no linear effect on waste generation nor in management (Calma, 2020; Naughton, 2020; Sarkodie & Owusu, 2020; Hantoko *et al.*, 2021; Shukla & Choudhary, 2022; Ranjbari *et al.*, 2023). Several studies reported a reduction in waste generation. In Tunisia, 85% of respondents to a survey indicated positive changes in food waste by adopting strategies such as saving, storing, and consuming leftovers (Jribi *et al.*, 2020). Morocco showed a reduction in municipal solid waste (Ouhsine *et al.*, 2020). In Shanghai, China, household waste decreased by approximately 23% (Van Fan *et al.*, 2021). In contrast, others found an increase in waste generation. Specifically, they highlighted an increase in non-recyclable materials, due to the high demand for home delivery as well as increase in organic waste resulting from home cooking during the pandemic (Dente & Hashimoto, 2020).

Waste composition also changed during lockdowns, particularly affecting food, plastic, and non-recyclable waste. One of the impacted fractions was organic (food) waste, which in some cases increased and in others decreased. On the one hand, increases were attributed to limitations in storage, overcooking habits, greater consumption of fresh products, and overbuying to achieve self-sufficiency during the pandemic (Heikal Ismail *et al.*, 2020; Jribi *et al.*, 2020; Qian *et al.*, 2020; Sharma *et al.*, 2020; Babbitt *et al.*, 2021; Brizi & Biraglia, 2021; Leal Filho *et al.*, 2021; Rodgers *et al.*, 2021; Sarda *et al.*, 2022). On the other hand, reductions were related to people spending more time at home, which made them more conscious about food losses (Ben Hassen *et al.*, 2021; Burlea-Schiopoiu *et al.*, 2021; Vittuari *et al.*, 2021). In general, the plastic fraction increased due to a rise in packaging waste, driven by the extended use of delivery services and online grocery shopping, as most gastronomic establishments were closed during the lockdown period (Dente & Hashimoto, 2020; Rhee, 2020; Sharma *et al.*, 2020; Zambrano-Monserrate *et al.*, 2020; Kitz *et al.*, 2021; Leal Filho *et al.*, 2021; Shukla & Choudhary, 2022; Ranjbari *et al.*, 2023). Finally, two phenomena may explain the increase in the non-recyclable waste fraction. First, the widespread use of face masks, gloves, and other disposable medical supplies increased. Second, pet adoption increased during the early stages of the pandemic, and remained high throughout, with a notable rise in cat adoption (Calma, 2020; Benson *et al.*, 2021; Ho *et al.*, 2021; Ranjbari *et al.*, 2023). In summary, food waste did not follow a single trend, whereas plastic and non-recyclable waste increased worldwide.

Ciudad Autónoma de Buenos Aires (CABA), like many other cities worldwide, experienced pandemic lockdowns but their potential effects on waste generation and composition have not yet been documented. Generated 430 g person^{-1} d^{-1} of household waste, 50% was organic, 29% reciclable, and the remainder non-recyclable (Pierini *et al*., 2021). The main factors influencing waste generation were the presence of pets and babies in the household, and whether meals were prepared at home (Pierini *et al*., 2021). In Argentina, the national sanitary emergency was declared on March 12, 2020 (Decree N$^{o.}$ 260/2020), establishing the implementation of mandatory preventive social isolation on March 20, 2020 (Drecree N$^{o.}$ 297/2020). These lockdowns imposed restrictions on mobility, and significantly curtailed commercial, educational, institutional, and tourism-related activities. Enforcement varied across different phases during 2020 and 2021, with measures generally being more stringent in CABA and its metropolitan area (Fitz Patric & Crucianelli, 2021). These measures led to significant socioeconomic impacts, including income loss, increased domestic and care tasks, and changes in food consumption patterns (INDEC, 2020). While the onset of the pandemic can be clearly defined, its end results less evident. Borders reopened on November 1, 2021 (Administrative Decision N$^{o.}$ 951/2021), and most activities resumed under specific health protocols (Decree N$^{o.}$ 678/2021). Therefore, for the purposes of this study, this date was considered a plausible estimate end of the pandemic period.

The aim of this study was to compare household waste generation patterns and composition across three distinct time period: (i) before (March 2019 to March 2020), (ii) during (March 2020 to October 2021), and (iii) after lockdowns (November 2021 to November 2022), in order to assess whether global patterns were replicated in CABA during lockdowns and whether they persisted afterward. A citizen science approach was employed, engaging non-scientist residents in data collection using researcher-designed protocols. This collaborative strategy not only enables large-scale and

temporally extended data collection but also promotes environmental awareness and community involvement in the issue under study (Brossard *et al.*, 2005; Conrad & Hilchey, 2011; Branchini *et al.*, 2015; Pierini *et al.*, 2021).

METHODOLOGY

Study system and temporal scope

CABA has a resident population of 3,121,707 within an area of 203 km² (INDEC, 2022). Approximately 2% of the city's population consists of infants (0-3 years old), while adults over 60 represent 22% (INDEC, 2022). Thus, the study sought to collect data representative of this area. Data collection began in March 2019 and ended in November 2022. For the purposes of this study three periods were established: before (March 1, 2019 to March 19, 2020), during (March 20, 2021 to October 31, 2021) and after (November 1, 2021 to November 30, 2022) COVID-19 pandemic lockdowns aligned with the restrictions imposed in Argentina, and CABA, during those periods.

Citizen science protocol and data collection

Participants were invited to voluntarily take part in the project, Observa:Residuos (www.labciudadano.net), to sort and weigh their household waste. They were provided with a digital scale (precision ±10 g). The protocol consisted of weighing and recording all household waste produced throughout a week, classified into five categories: (i) paper and cardboard, (ii) plastic, (iii) other recyclable waste (metal, glass, fabric), (iv) organic waste, and (v) non-recyclable (*i.e.* residual waste). At the end of the week, participants uploaded their records to a web application especially developed for this project, hosted on www.labciudadano.net and answered a short questionnaire detailing household composition, including age groups and the number of pets, specifying whether they were dogs, cats, or others. To see more details of the protocol, please refer to Pierini *et al.* (2021).

Data were obtained from a total of 828 households (2,275 inhabitants) representing 0.07% of total population. Data collection was conducted over three distinct time periods described earlier: (i) before lockdowns: 526 households (1,332 inhabitants), (ii) during lockdowns: 153 households (392 inhabitants), and (iii) after lockdowns: 149 households (551 inhabitants).

Data analysis

The data on total waste generation and its fractions exhibited a right-skewed distribution, with a concentration of low values of waste generation. Given the continuous, non-negative, and right-skewed nature of the data, generalized linear models were fitted assuming a Gamma distribution with a log link function. The Gamma distribution is particularly suitable for modeling self-reported waste generation, as it accounts for the variance structure and avoids the need for data transformation (Zuur *et al.*, 2009). Although most observations were strictly positive, some values equaled zero grams. To retain these valid data points and enable model fitting, a small constant (0.1 g) was added. This adjustment is negligible in practical terms, especially considering the precision limits of the scales used (±10 g). Models were assessed for goodness-of-fit using residual plots and deviance statistics to ensure their appropriateness. Statistical outliers —defined as values exceeding 1.5 × the interquartile range (IQR)— were identified and were retained because, although they fall outside the central distribution, they capture genuine heterogeneity in household waste generation rather than data artifacts.

The organic, recyclable, and non-recyclable fractions were compared among the three stages (before, during, and after lockdowns) to analyze differences in the relative composition of waste. Normality assumptions were first tested, and since the data did not conform, a non-parametric Kruskal–Wallis test was applied followed by Dunn's multiple comparison test with Bonferroni-adjusted p-values to identify significant pairwise differences. These analyses were conducted in R version 4.1.2 (RStudio 2024.04.2+764 "Chocolate Cosmos" for Windows), using the Dunn Test function from the FSA package (Ogle *et al.*, 2025). Significance was evaluated at the $\alpha = 0.05$ level, for each fraction (total waste, organic, non-recyclable, recyclable, and its subfractions —paper and cardboard, plastics, and other recyclables) across the three periods analyzed.

RESULTS & DISCUSSION

The sample broadly reflected the age structure of CABA, although individuals over 60 were underrepresented —probably due to difficulties in using the web application. During and after lockdowns, the proportion of infants doubled compared to CABA's population,

while after lockdowns the sample showed an overrepresentation of individuals aged 13-18, probably due to their participation in a school project associated with this citizen science study. Before lockdowns, 18% of households had at least one dog, another 18% had at least one cat, and 6% had both a dog and a cat, with at least one of each species. During lockdowns, these proportions remained stable, except for households with at least one dog, which increased to 24%. After lockdowns, dog ownership levels were maintained, households with both a dog and a cat rose to 16%, and those with only cats decreased to 14%. Thus, while exclusive cat ownership declined, the total number of households with cats remained stable or even increased, and households with dogs increased, indicating a rise in pet presence overall.

Among all waste fractions, only the generation of non-recyclable materials increased significantly during pandemic lockdowns compared to the values obtained before (p= 0.007) (Figure 1). This trend may be partially explained by the rise in the number of households that included at least one cat —either exclusively or alongside a dog— which may have increased sanitary waste to the non-recyclable fraction, as highlighted in

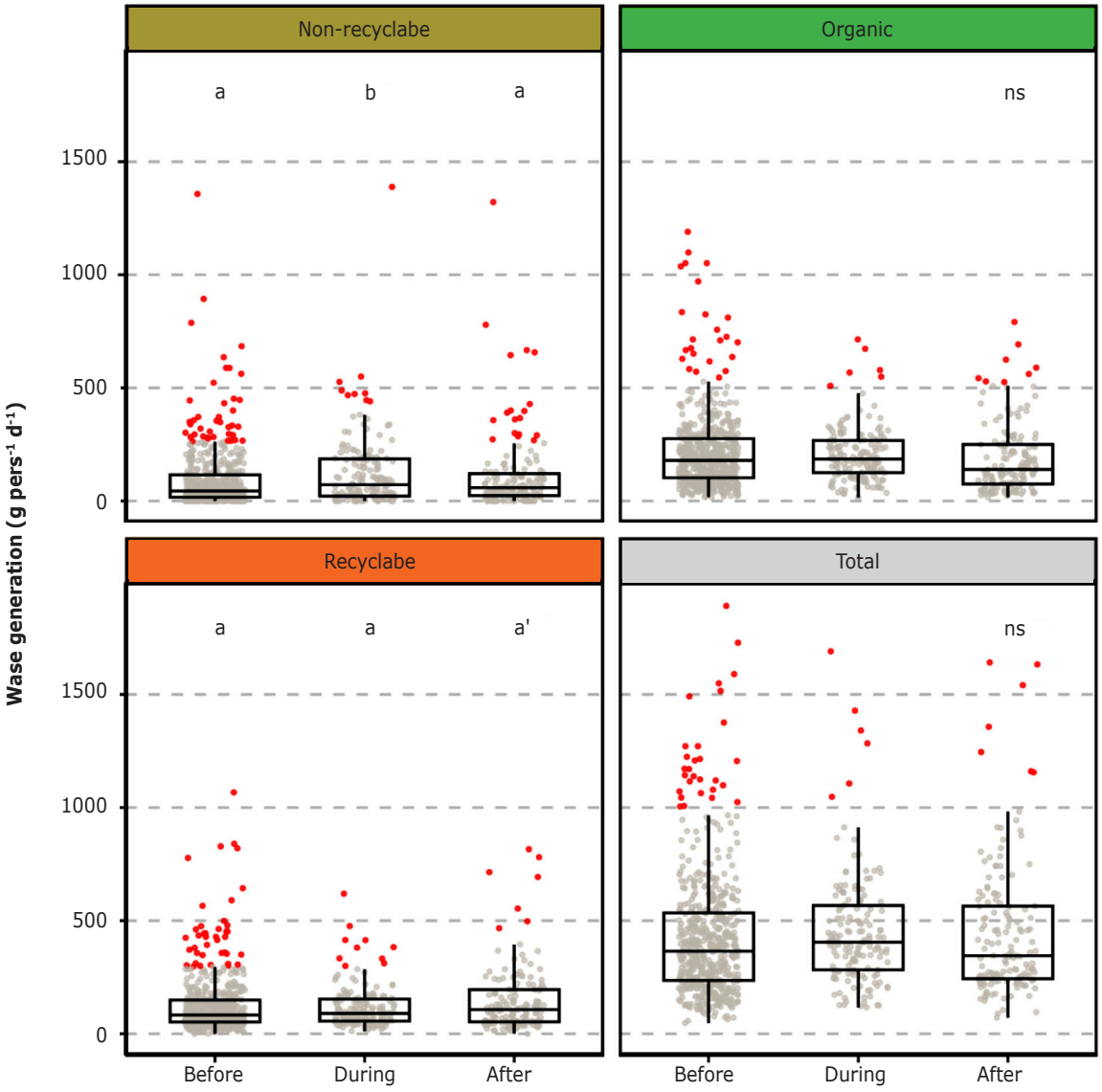

Figura 1. Household waste generation (g person^{-1} d^{-1}) by fractions (total, organic, recyclable, and non-recyclable) before (March 1, 2019 to March 19, 2020), during (March 20, 2021 to October 31, 2021) and after (November 1, 2021 to November 30, 2022) COVID-19 lockdowns in Ciudad Autónoma de Buenos Aires (CABA), Argentina. Different letters indicate significant differences within the same fraction across periods (p< 0.05); ns: indicates non-significant differences across periods. a': indicates marginally significant differences (p= 0.06). Each dot represents a household measurement. Boxplot whiskers represent 1.5 times the interquartile range (IQR). Data points outside this range were considered outliers (red).

previous research (Pierini *et al.*, 2021). Media reports have suggested that the rise in pet adoption during pandemic lockdowns could be related to emotional factors such as loneliness and social isolation (CNN Radio Argentina, 2021; Unidiversidad, 2021; Pacheco, 2022). However, the causal relationship between these variables remains to be investigated. Additionally, the increase in residual waste may reflect the widespread disposal of used face masks, gloves, and other single-use medical supplies (Calma, 2020; Benson *et al.*, 2021; Ranjbari *et al.*, 2023).

In contrast to non-recyclables, recyclable waste generation showed a marginal increase after lockdowns ($p= 0.06$) (Figure 1). This trend could be attributed to changes in the generation of paper and cardboard, and plastics, all of which increased significantly after lockdowns ($p= 0.04$ and $p= 0.01$, respectively) (Figure 2). The generation of other recyclable fractions remained relatively stable throughout the period analyzed. Lockdowns in many countries led people to purchase groceries and other supplies online, which likely caused a surge in packaging waste—paper and plastic (Sharma *et al.*, 2020; Leal Filho *et al.*, 2021; Shukla & Choudhary, 2022).

Contrary to what was expected, organic and total waste generation did not change significantly over the period analyzed (Figure 1). For both variables, this trend may be explained by the economic challenges faced during the pandemic, as Argentina's pre-existing high inflation worsened during and after lockdowns, limiting household purchasing power and changing food consumption patterns and meal preparation routines (Alzúa & Gosis, 2020; INDEC, 2020). Additionally, more mindful grocery shopping behaviors, such as minimizing expenses and reducing trips to avoid virus exposure, likely prevented organic waste from growing (Babbitt *et al.*, 2021). Finally, cooking and eating more comfort food or snacks instead of fresh vegetables or fruits could also have contributed to this result, possibly driven by increased stress and emotional strain reported in households during lockdowns (INDEC, 2021; Sarda *et al.*, 2022). In summary, on average, total household waste was 427±278 g person^{-1} d^{-1} before lockdowns, 453±250 g person^{-1} d^{-1} during lockdowns, and 447±298 g person^{-1} d^{-1} after lockdowns, with no significant differences observed across the three periods (Figure 1).

Waste composition exhibited modest variations throughout the study period (Figure 3). The proportion of organic materials declined significantly after the pandemic stage, whereas the proportion of recyclables increased

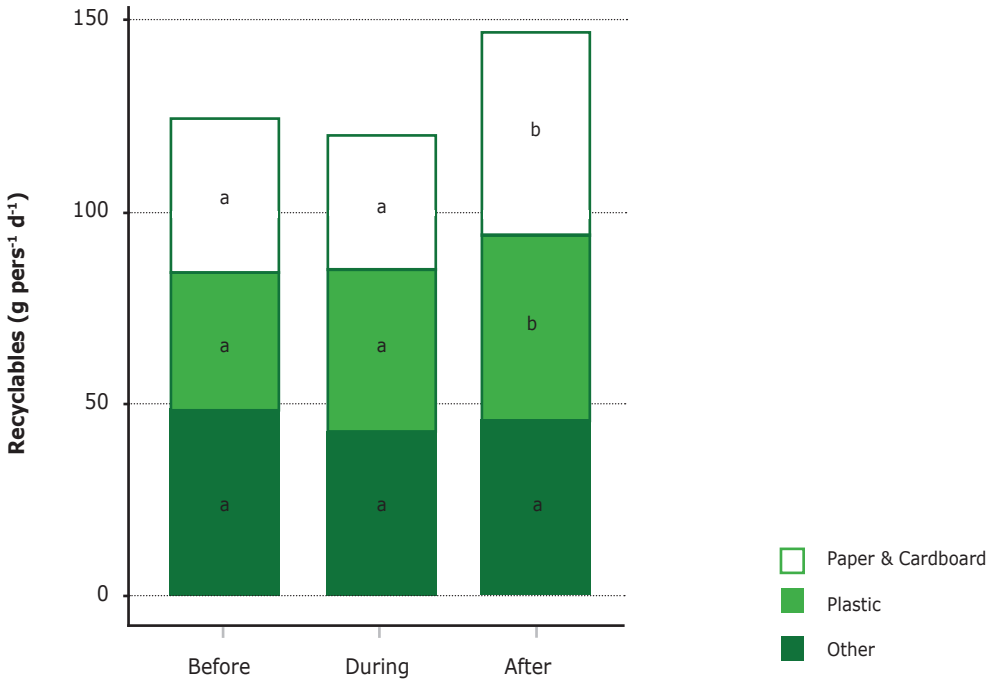

Figura 2. Composition (g person^{-1} d^{-1}) of the recyclable fraction of household waste (paper and cardboard, plastics, and other recyclables) before (March 1, 2019 to March 19, 2020), during (March 20, 2021 to October 31, 2021) and after (November 1, 2021 to November 30, 2022) COVID-19 lockdowns in Ciudad Autónoma de Buenos Aires (CABA), Argentina. Other recyclables include metals, glass and fabric. Different letters indicate significant differences within the same fraction across periods ($p< 0.05$).

relative to the lockdown period and was nearly —though not significantly— higher than pre-pandemic levels. In contrast, the non-recyclable fraction reached its highest value during lockdown. By the end of the study, household waste consisted of 42% organic, 33% recyclable, and 25% non-recyclable materials. In the future, as online shopping and delivery services continue to expand, it will be important to assess how household online purchasing behavior drives the generation of recyclable materials, and whether this increase is accompanied by practices that promote waste separation for recycling. Additionally, if purchasing power recovers it would be interesting to confirm whether organic fraction recovers pre-pandemic levels. In this context, citizen science once again proved to be a reliable and scalable tool for detecting changes —or their absence— in waste generation and composition. Its participatory nature makes it especially valuable for municipal governments seeking to improve data collection and foster environmental awareness among residents.

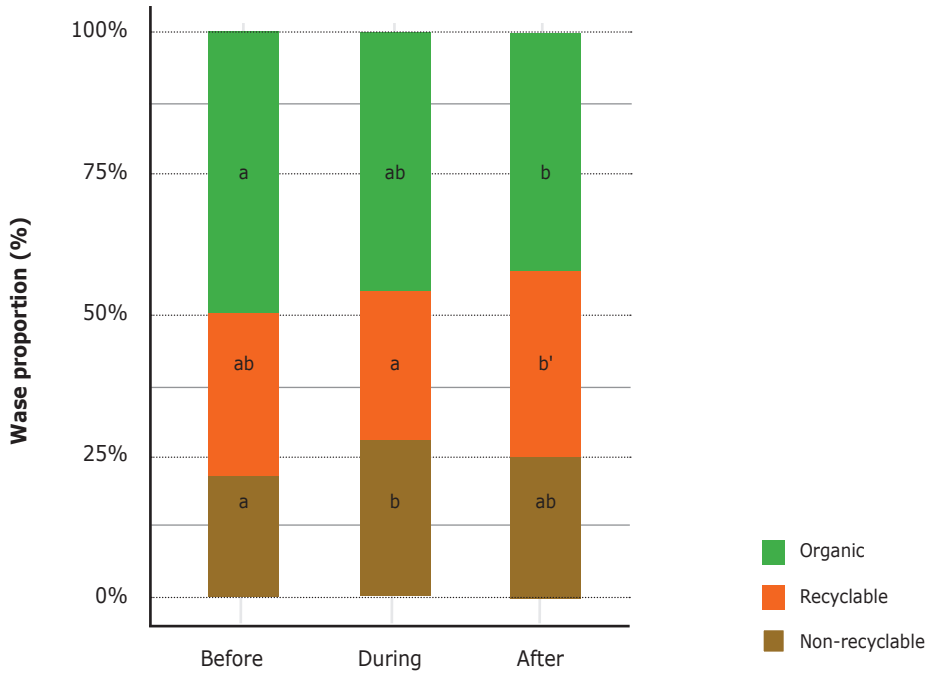

Figura 3. Household waste composition —organic; recyclable; non-recyclable (*i.e.* residual waste); %— before (March 1, 2019 to March 19, 2020), during (March 20, 2021 to October 31, 2021), and after (November 1, 2021 to November 30, 2022) COVID-19 lockdowns in Ciudad Autónoma de Buenos Aires (CABA), Argentina. Different letters indicate significant differences within the same fraction across periods ($p < 0.05$); b': indicates marginally significant differences ($p = 0.06$).

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