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Exploring dark kitchens in Brazilian urban centres: a study of delivery-only restaurants with food delivery apps

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Abstract

Dark kitchen is a delivery-only restaurant that operates without direct contact with the consumer, has no premises for local consumption and sells exclusively through online platforms. The main objective of this work is to identify and characterise dark kitchens in three urban centres featured in the most used food delivery app in Brazil. To this end, data collection was conducted in two phases. In the first phase, through data mining, we collected information from restaurants in three cities (Limeira, Campinas, and São Paulo - Brazil) that were provided in the food delivery app. A total of 22,520 establishments were searched from the central point of each of the cities. In the second phase, the first 1,000 restaurants in each city were classified as dark kitchens, standard, or undefined restaurants. A thematic content analysis was conducted to further distinguish the dark kitchen models. Of the restaurants evaluated, 1,749 (65.2%) were classified as standard restaurants, 727 (27.1%) as dark kitchens, and 206 (7.7%) as undefined. In terms of the characteristics of dark kitchens, they were more dispersed and located further away from the central points compared to standard restaurants. Meals in dark kitchens were cheaper than in standard restaurants, and had a lower number of user reviews. Most of the dark kitchens in São Paulo served Brazilian dishes, while in the smaller cities, Limeira and Campinas, it was mainly snacks and desserts. Six different models of dark kitchen were identified: Independent dark kitchen; shell-type

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(hub); franchise; virtual kitchen in a standard restaurant (different menu); virtual kitchen in a standard restaurant (similar menu but different name); and home-based dark kitchen. The modelling approach and methodology used to classify and identify dark kitchens is considered a contribution to science as it allows a better understanding of this fast growing sector of the food industry. This in turn can help to develop management strategies and policies for the sector. Our study is also of value to regulators to determine their proliferation through urban planning and to promote appropriate guidelines for dark kitchens as they differ from standard restaurants.

Keywords: food service; cloud kitchen; virtual kitchen; ghost kitchen; food delivery;

Word-count: 6978 (without tables and references)

1. Introduction

The use of food delivery apps is becoming more commonplace in people's everyday lives. As a result, the market for food delivery has grown exponentially in Brazil and worldwide in recent years (CREST & Grupo, 2020; Statista, 2022b). This scenario has contributed to the emergence of a new trend in the food industry: dark kitchens. There are many names for dark kitchens such as: cloud or ghost kitchens, invisible, shared, commissary, satellite, virtual, or even cyber kitchens (Chatterjee et al., 2022; Dian et al., 2021; John, 2021; Upadhye & Sathe, 2020). These food businesses are characterised by having no spaces for local consumption, no direct contact with the public, and selling exclusively through online platforms (Khan, 2020).

It is estimated that dark kitchens are not just a temporary solution. Sales are forecasted to reach USD 0.91 trillion in 2023 worldwide, with annual growth of 12.33% by 2027 (Statista, 2022b). According to Euromonitor projections, the global dark kitchens will potentially unlock USD 1.5 trillion opportunities by 2050 (Euromonitor, 2019). Although all dark kitchens showed high growth through increased sales, many experienced low market share averaging low to medium profits (Susilowati et al., 2021). So, food entrepreneurs who open a restaurant to sell food online may struggle to develop efficient strategies to make a profit.

Based on the increased sales, dark kitchens still seem to be a promising business model. However, few studies look at how dark kitchens work, organize themselves and their management strategies. Previous studies were focused on determining consumers' preference or acceptance of dark kitchens (Ahmed Khan et al., 2022; Kulshreshtha & Sharma, 2022), willingness to pay (Hakim et al., 2022), and types of food and drinks sold (Rinaldi et al., 2022). Nevertheless, despite the clear development of the phenomenon described, researchers emphasise that there is still a gap in studies on dark kitchens, especially in countries where dark kitchens are proliferating (Cai et al., 2022; Kulshreshtha & Sharma, 2022). Several studies (quantitative, qualitative, and mixed-method approaches) have been conducted on the markets in India, Indonesia, the US, and the UK (Khan et al., 2023) or in Italy and Poland (Varese et al., 2023) on the prospects of dark kitchens and meal delivery apps, but few in the Brazilian market (Hakim et al.,

2022). The role of consumers in understanding, buying and patronising dark kitchens is also unclear. Although recent studies have shown a positive willingness to buy food produced in dark kitchens, including in Brazil (Cai et al., 2022; Hakim et al., 2022), there are some barriers to understanding consumers' intentions towards this restaurant model. The first issue is that consumers still do not really know what dark kitchens are (Hakim et al., 2022).

The second issue is that the food delivery apps in Brazil are an obstacle in identifying these venues, as there is nothing on the user interface of these apps that distinguishes a standard restaurant from a dark kitchen. Therefore, even if a person knows about the existence of these food services, they cannot quickly identify them to make their choice. It is currently unknown what percentage of dark kitchens offer services in the various food delivery apps and countries. However, given the growing trend, it is essential to characterise this new food service sector and understand the role of dark kitchens in the food-consumer relationship.

Despite some classifications, we believe that dark kitchens in Brazil can have different features. With this in mind, we posed the following research questions: Q1: Where are these dark kitchens located in Brazilian urban centres? Q2: What features of dark kitchens differ from standard restaurants? Q3: What kind of food, cuisines, and menus are offered in dark kitchens in Brazil? Q4: How is this kind of model organised in Brazil? Hence, the main objective of this work is to identify and characterise the dark kitchens in three urban centres that are featured in the most commonly used food delivery app in Brazil.

Our research has implications for the body of scientific knowledge and practice. Achieving this goal and answering the questions will enable a better understanding of this rapidly growing sector and the role of dark kitchens in the relationship between food and consumers. Thus, data on the characteristics of dark kitchens could support further, more in-depth research to find out which model is most efficient and effective in meeting consumer demands. In terms of practical implications, we believe that the results of our research can help the government understand the impact of dark kitchens on the economy and public health. Next, the results of the study will provide food authorities with better information to ensure food safety, maintenance of cold chain during delivery, and essential information such as food allergens are disclosed (Southey, 2021). The answers will also be used to understand the spatial pattern and agglomeration of the dark kitchens (Safira & Chikaraishi, 2022). On the other hand, the growth trend of this industry is pushing for knowledge that can serve as a basis for regulating the sector. Currently, only one city in Brazil (São Paulo) regulates dark kitchens (Brasil, 2022), which differs from standard restaurants. This work attempts to explore the dark kitchens in Brazil in an innovative way. There is no clear method to identify dark kitchens. Therefore, we combined several technological strategies to explore the dark kitchens in the most used food delivery app in Brazil. The proposed method is suited to identify food services that were not advertised or easily identified as dark kitchens in food delivery apps or company websites.

2. Dark kitchens - Literature review and contextual background

In recent years, the food delivery market, which includes services that deliver food ordered through very different channels for direct consumption, has gained popularity worldwide. This phenomenon refers to the restaurant-to-consumer delivery segment, which includes food delivery made directly by restaurants for orders placed through platforms (platform-to-consumer delivery), as well as through restaurants' websites, apps and social media, or by phone/email (Nigro et al., 2022).

Food delivery systems have a long history, and one of the oldest originated in Korea in the 14th century (Torres, 2021). Researchers also cite an example from Italy, from 1889, when Italian King Humberto and Queen Margherita asked taverna owner Raffaele Esposito to bring them pizza to the palace (Gamilla, 2021). Soon after, in 1890, during the British colonial period, another system known as Dabbawala (a lunchbox delivery and return system) was established in India, to provide the British population with non-local food (Mahadevan, 2021).

Dark kitchen is a recent phenomenon supported by the evolution of food delivery systems and technological development in the early 2010s. This phenomenon arose in response to increased demand for high-quality meal delivery and rising rents in city center locations (Sisodia & Nair, 2021). These kitchens have lower opening and maintenance costs than a standard restaurant due to their simpler structure and are therefore attractive from an economic perspective (Restaurant Owner, 2020; Giousmpasoglou et al., 2023). The possibility of the emergence of this business model arose with the creation of mobile applications as a solution to the population's need for easy shopping (Smith et al., 2013). COVID -19 accelerated the growth of dark kitchens as a reflection of the economic destabilisation at the time. During the worst of the pandemic, when people stayed at home, restaurants were forced to close their doors, creating the need for alternative outlets (Chang et al., 2021; Talwar et al., 2021). Later, when shops reopened, there was still a barrier for many consumers to avoid restaurants for fear of contracting COVID -19 (Hakim et al., 2021).

Although the sector is recognised by many names, there is neither a clear definition nor an established industry conversation (Khan, 2020). In this sense, there have been efforts in recent years to improve the sector, including its terminology and definitions. For example, the International Organisation for Standardisation (ISO) has recently published guidelines on the subject described, distinguishing the terms "virtual kitchen" and "virtual restaurant" as follows (IWA 40, 2022): virtual kitchen - commercial cooking space without a dine-in or retail option that provides a centralised, standardised, and digitised catering service with hardware and software support facilities or site resources for multiple virtual restaurants to share resources for catering operations; virtual restaurant - main body that carries out catering business activities through a virtual kitchen and that includes individuals, enterprises, and other organisations. Several classifications of kitchen models can be found in the literature, taking into account the type of online application used (Lestari, 2022), the form of ownership (property, rental) (Muangmee et al., 2022), or the type of food served (e.g., dessert, burger, chicken, Chinese, Italian, etc.) (Rinaldi et al., 2022).

In practice, dark kitchens around the world, operate with a variety of business models, both organisational and technically. For example, John (2021) made a categorisation based on the models of dark kitchens presented by an Indian restaurant support software company (Maggo, 2018): independent cloud kitchen model (i.e., traditionally delivery-only restaurant), the brand house model (i.e., multi-brand kitchen for multiple cuisines), the storefront franchise model (i.e., a single brand in a single kitchen, but multiple outlets and a visible storefront), aggregator-owned (shell-type) model (i.e., multi-brand offering owned by an aggregator with rented kitchens), and fully outsourced model (chefs only do final touches and finishing). However, the organisation of services and opportunities for growth vary from culture to culture. This diversity of definitions and the typology presented show the important role that dark kitchens and FDA play for consumers.

Researchers here emphasise cognitive, developmental and social relevance due to the need to use information technology (Prabowo & Nugro, 2019) with specific needs and demands. In this context, it is also important to actively participate in the development of innovative solutions and sometimes in testing them (Cho et al., 2019). For example, consumer expectations of food delivery by drone have been recognised (Hwang et al., 2019). From a risk-benefit point of view, this type of solution enables the fulfilment of requirements such as: Hygiene and protection from possible contamination (Sharma et al., 2021), payment security (Chowdhury, 2023), a wide choice of menus (Kong et al., 2023), and time and labour saving (Gani et al., 2023). Extensive research on consumer intentions and benefits associated with food delivery apps has recently been conducted by Hong et al. (2023), among others. It is also interesting to note that delivery platforms are increasingly recognising where dark kitchens can meet underserved demand (MAPIC, s/d).

It should also be noted that delivery-only food services are not free of constraints, both from restaurateurs' and consumers' perspectives. This includes challenges of maintaining the right temperature, including the cold chain (Ahmad Nizar & Zainal Abidin, 2021), as well as the hygiene of the containers and couriers delivering the food (Puram et al., 2022). According to professionals, seating and waiting areas in traditional restaurants offering food delivery services are increasingly underutilised or even empty, putting pressure on restaurant profitability. Secondly, serving customers while preparing food for delivery - at the same peak time of the day would potentially result in deterioration of customer experience due to longer waiting and delivery times (Ahuja et al, 2021; MAPIC, s/d).

The above considerations confirm that the described phenomenon is very developmental and dynamic, and that its role and importance on the food market will systematically grow.

3. Methods

Data collection was performed in two stages: i. automated step and ii. manual step. In the automated stage, data was collected through the website of the Ifood® platform (<https://www.ifood.com.br/>), the most commonly used food delivery app and food delivery operator in Brazil (Chevalier, 2022). Ifood® has more than three hundred

thousand food services with more than sixty million orders per month in over 1700 cities across Brazil (iFood, 2021) and it is the most used food delivery app in Brazil (Statista, 2022a).

3.1 Automated step

The automated step was carried out using data mining to extract information from public internet pages. Python scripts were used to access the desired content using the JSON (JavaScript Object Notation) representation standard in the search for the desired web page. The data collection was done considering the restaurants listed on the Ifood® website for Limeira, Campinas, and São Paulo cities. The cities are all from the state of São Paulo, the largest and most developed state in Brazil. The cities were selected based on the classifications established by REGIC (Regions of Influences of the Cities). Limeira is Subregional Centre B (308,482 inhabitants), a category for cities that exert influence on surrounding municipalities. Campinas is a metropolis (1,223,237 inhabitants), a classification for urban centres of great centrality that span several territories and have a relevant population contingent - more than 2 million inhabitants - and is the only non-state capital with this classification in Brazil. Finally, São Paulo is a Great National Metropolis (12.3 million inhabitants), the only city with this classification, with the highest urban hierarchy in the country (IBGE - Instituto Brasileiro de Geografia e Estatística, 2018).

The following information were extracted from the scripts: URL (Uniform Resource Locator) of the restaurant, name of the restaurant, linear distance of the restaurant from the city centre (as the starting address for the search), estimated delivery time, rating of the restaurant given by users (5-point scale where '1-poor' and '5-excellent'), number of users who rated the restaurant, price rating (5-point scale where '1-cheapest' and '5-most expensive restaurant' – This classification is automatically made by the platform based on quantile), category of the restaurant (i.e., type of food offered), address information, CNPJ number (National Registry of Enterprises number) of the restaurant, whether the restaurant accepts scheduling of deliveries and taking-out of orders, and whether the restaurant allows tracking of the location of the order until its delivery by using the logistics provided by iFood® itself. Every restaurant registered on iFood® must have a CNPJ, i.e., it must be registered as a restaurant with public bodies. The geographically central points of the cities designated for the search were: in Limeira 500-576 Boa Morte street – Centro, Limeira – SP (zip code 13480-181); in Campinas 1000 Francisco Glicério avenue – Centro, Campinas – SP (zip code 13012-100); and in São Paulo, Cel. Fernando Prestes square – Bom Retiro, São Paulo – SP (zip code 01124-060). These addresses were chosen because they are geographically located in the centre of the respective cities.

3.2 Manual step

The second step was done manually to assess whether restaurants might be dark kitchens. This step was carried out with the first 1,000 restaurants in each of the cities of Limeira (85.4% of the total available restaurants in food delivery app), Campinas (47.8% of the total), and São Paulo (6% of the total). Dark kitchens were classified according to the assumptions of Khan (2020), i.e., food services without local service to the public, offering meals transported by delivery and where there is no direct contact with the consumer. Home-based, rented, or shared premises, common to this type of business were included in this context. Establishments which were not exclusively food services were excluded (i.e., pharmacies, supermarkets, flower shops, convenience stores etc.).

This stage was conducted in an investigative and exhaustive manner. First, Google®Street View was used to visualize the establishment's storefront, and an assessment was made of the information available about the establishments on social networks and Google searches. In cases where the data collected were insufficient, a three step verification process was made to contact the establishments directly, i.e., via (i) telephone, (ii) e-mail, and (iii) available social networks. This approach was important to look for information beyond the virtual visualization of the premises' storefront, as some Google Street View data may be outdated due to the opening of new establishments that were not included in the latest Google Maps update. Based on this information and definition of dark kitchens by Khan (2020), the restaurants were classified according to the criteria in figure 1.

[Figure 1]

The data collection was carried out between December 2020 and January 2023. To test the methodology's appropriateness, automatic data collection was first carried out on 20 December 2020 concerning the city of Limeira and a manual evaluation was carried out in 2021. Once this step was completed and the proposed methodology confirmed, automated surveys were carried out in Campinas and São Paulo cities on 11 January 2022. The data found were analysed manually until 3 January 2023.

In Ifood®, restaurants are divided according to categories of food for sale. These categories are used to help consumers get a better understanding of what the restaurant has to offer, or even to filter their searches according to their interests. Due to the wide variety and over-specification of types of food, six categories were created: i. Brazilian food (Brazilian, Meat, Frozen, Chicken, Lunchbox, Fish, Healthy food, Soups and broths, Varied, Frozen, Seafood, Typical dishes from different Brazilian states, Pancakes, Vegan, and Vegetarian categories), ii. Ethnic Food (Arabic, Chinese, Contemporary, French, Italian, Mexican, African, German, Argentinian, Asian, Colombian, Korean, Spanish, Greek, Indian, Mediterranean, Peruvian, Portuguese, Thai, and Yakisoba categories); iii. Snack (Hamburger, Snack, Pastel, Savoury Snack, *Tapioca*

[a food consisting of white grains, rather like rice, which come from the cassava plant], and Crepe categories); iv. Pizza (including only pizzerias); v. Desserts (*Açaí* [popular ice cream-like Brazilian dessert], Sweets and cakes, and Ice cream categories); and vi. Bakery and café (Bakeries, Cafeteria, and Juice shop categories). The categories were grouped independently by two researchers and then discussed to reach a consensus.

3.3 Georeferencing

After data collection, all restaurants were graphed using Power BI software (Microsoft - USA). The restaurants classified as 'dark kitchen', 'standard restaurant' and 'undefined' were clearly identified, as was the central point of each city. All restaurants were plotted using longitude and latitude coordinates using decimal degrees ranging from -90 to 90 for latitude and -180 to 180 for longitude.

The density in the centre was calculated considering all dark kitchens and standard restaurants within 5-km² of the centre. The total number of restaurants was divided by 5 to standardise the measure to square kilometres (km²).

A buffer was created around the boundaries of each city centre. As the cities differed significantly in size and population, different buffers were created: 2.5km² for Limeira, 3.4km² for Campinas, and 5.8km² for São Paulo. These values were the median distance from the central point of the city. They also correspond to approximately 1% of the size of the urban area of each city. Buffers ranging from 800 m to 5 km were used in previous studies that evaluated the density and proximity of food stores (Maguire et al., 2017; Thornton et al., 2012; Turrell & Giskes, 2008).

3.4 Classifying dark kitchens models

The dark kitchen models were further classified based on data collected from the websites, Ifood® platform, Google Street View, and social media. The data collected from the restaurants cited in the automated step methods were inserted into a sheet. A column was added for observations about dark kitchens and their characteristics (e.g., the type of storefront and public information about the restaurant). The data analysis followed the principles of thematic content analysis, a qualitative method comprising grouping techniques and categorising them based on similar meanings or intersections of characteristics (Bardin, 2016).

In the qualitative analysis, the dark kitchens were classified based on the presence or absence of a storefront, address, infrastructure features, menu information, CNPJ number, public information on the internet, and direct contact with the establishment (by phone, email, or via social media).

3.5 Data analysis

The theoretical distributions of the quantitative variables were analysed using means, variances, skewness, kurtosis, and histogram. The Kolmogorov-Smirnov test (with Lilliefors correction) was used to check the normality of the data. To compare two independent groups (standard restaurants and dark kitchens), the t-Student test was used. Correlations were made by using Pearson's correlation coefficient. Three logistic regression models were constructed, one for each city, namely Limeira, Campinas, and São Paulo. The dependent variable was the presence of dark kitchens in the buffer zone. The independent variables were included in a multiple model after they showed significant values in the single model. The exponential value of beta was used to estimate the odds ratio (OR). Goodness of fit was measured using the Hosmer and Lemeshow test. The bootstrap procedure with 1,000 samples was used where appropriate to normalise the data. The bootstrap quality was measured by analysing the 95% confidence intervals.

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS) v.20 software. For all analyses, values of $p < 0.05$ were considered significant.

4. Results and Discussion

4.1. Characterising dark kitchens

After the automated step, the sample consisted of 22,520 establishments, 1173 in Limeira, 4780 in Campinas, and 16,567 in São Paulo. This total number corresponds to all the restaurants in the search from the given central point. With this data, we analysed 3,000 establishments (1,000 from each city) in the manual step, classifying 1749 (65.2%) as standard restaurants, 727 (27.1%) as dark kitchens, and 206 (7.7%) were undefined. Under the Ifood® rules, establishments that are not restaurants (i.e., markets, beverage retailers, florists, gift shops, and others) can also make sales in the application. Since this study focused on dark kitchens, all establishments that are not exclusively food services were excluded from the sample ($n=318$).

The city with the highest percentage of food services classified as dark kitchens was São Paulo, measuring 35.4% (Table 1). With more than 12 million inhabitants (IBGE, 2023), São Paulo is ranked as the 21st largest economy in the world (Casa Civil do Estado de São Paulo, 2020). Still, it is a city with large socio-economic gaps (Rodrigues & Paiva, 2022). This scenario shows the profile of a city attractive to new investment because of its wealth. In addition, dark kitchens emerged in large urban centres to meet the demand of discerning customers (Sisodia, 2021). Such notes can justify the greater presence of dark kitchens in a big city like São Paulo. However, it was found that in smaller cities (e.g., Campinas, and Limeira) dark kitchens accounted for more than 20% of the total food services. This result suggests that this model has also gained acceptance in smaller cities.

[Table 1]

Answering the first research question (Q1), in all cities, it was found that dark kitchens were located further away from the central point than standard restaurants (Table 2). The density of standard restaurants was higher than dark kitchens in the city's central region. Figure 1 shows the map of the three cities and the heatmap for dark kitchens and standard restaurants. The maps show the highest density of standard restaurants in the centre (Figures 2B, 2D, and 2F). Although there were several dark kitchens in the centre of the cities, it can be seen that dark kitchens were scattered in the neighbourhoods and do not follow certain patterns and agglomerations (Figures 2A, 2C, and 2E). There was also a positive correlation between distance from the central point and delivery time for Limeira ($r=0.37$; $p<0.001$), Campinas ($r=0.56$; $p<0.001$), and São Paulo ($r=0.27$; $p<0.001$).

[Table 2]

Location is important for a standard restaurant (Fisher, 1997). A restaurant that serves its target audience locally needs to be easily accessible by transport and close to customers and city's commercial conurbations, such as city centres (Chidambaram & Pervin, 2018; Jung & Jang, 2019; Prayag et al., 2012; Wrigley et al., 2016). Dark kitchens, on the other hand, do not need this attribute, and they can be located further away from business centres and benefit from lower rents and fixed costs. This result echoes Talamini et al. (2022) in China and Safira & Chikaraishi (2022) in Jakarta, Indonesia, which showed a greater dispersion of locations for dark kitchens. The location of this business model has already led to discussions about urban development in the state of São Paulo, where dark kitchens were indeed more prevalent. There have been many complaints about excessive noise and even the smell of grease near dark kitchens in residential neighbourhoods (Vieira, 2022). This problem prompted the creation of the first law regulating dark kitchens in Brazil to reduce the urban problem (Brasil, 2022). In this way, legislation can contribute to the acceptance of this business model among the population, as there are rules that make co-existence more peaceful and less invasive.

In Table 2, many different characteristics of dark kitchens compared to standard restaurants are observed. This section answers the second research question (Q2). In terms of price range, there was a difference between standard restaurants and dark kitchens in all cities, with the average being higher for standard restaurants. This result was expected, given the lower fixed costs of dark kitchens and the brand equity of conventional restaurants (Restaurant Owner, 2020). Price is a major factor in consumers' food delivery app decision-making process, as their purchase intention is positively influenced by the value of price (Tam et al., 2020; Tandon et al., 2021; Venkatesh et al., 2012; Zanetta et al., 2021). This positive relationship between price and purchase intention is no different for dark kitchens, as price seems to influence purchase intention in this model (Hakim et al., 2022). Although price is not the only factor considered in a purchase decision, it may increase the tendency to choose a dark

kitchen compared to a standard restaurant. In terms of the market, this can be a barrier for standard restaurants, which have higher maintenance and fixed costs than dark kitchens (Restaurant Owner, 2020) and could hardly compete with dark kitchens in the e-market based on food price. On the other hand, standard restaurants are perhaps better known and possibly more established than dark kitchens and therefore have a stronger brand. The brand is another critical aspect in the decision-making process. The true power of a brand lies in the minds of consumers, it is a mental construct, based on what consumers experience and learn about the brand over time (Keller & Brexendorf, 2019). This mental construct affects how consumers respond to products, prices, communications and other marketing activities, increasing or decreasing brand equity in the process (Keller & Brexendorf, 2019). Thus, the brand can contribute to the interpretation, processing and storage of information about products and services, affect trust (i.e., a customer feels more comfortable with one that they had experienced, is considered of high quality or is familiar) (Dirsehan & Cankat, 2021; Ho-Dac et al., 2013) and form the perception of value, providing a reason to buy, differentiating the brand and supporting higher prices (Aaker, 1992).

[Figure 2]

We also observed that dark kitchens received fewer number of user ratings than standard restaurants, although the scores were different only in São Paulo. With app-based food purchases, there is an expected process from the user during their decision making. This process usually starts with finding a favourite restaurant (Pigatto et al., 2017). When a restaurant is newly opened, it is less preferred and patronised as there is no prior knowledge about it. Also, as previously mentioned, the brand builds trust with the consumer (Keller & Brexendorf, 2019). Despite the growth of dark kitchens, standard restaurants are probably better known and recognised than dark kitchens. This can lead to a greater number of sales and therefore a greater number of consumers to rate, which explains the result. Some non-food apps also link bonuses to customer reviews (Wu et al., 2019). The metrics associated with boosting in the app were unknown, but potentially these reviews could influence how a restaurant is advertised. The volume of online reviews in other industries is positively related to consumer satisfaction, company reputation, and profitability (Nieto et al., 2014). Therefore, this data could be important for survival perspective in terms of marketing. Boosting sales may also naturally result from consumer ratings for app purchases, as this rating serves as a quality control for future consumers' perceptions (Ray et al., 2019) which may increase or decrease purchase intent.

Answering the third research question (Q3), in São Paulo, the Brazilian food category was most prevalent in both dark kitchens (30.3%) and standard restaurants (32.9%). It was to be expected that many dark kitchens would offer typical Brazilian food, especially in larger centres such as São Paulo and Campinas, where traffic and distance

between home and work are greater. Many dark kitchens offer utilitarian meals, i.e., they serve consumers who want a quick and cheap lunch or dinner but do not refrain from eating complete meals (e.g., a combination of rice, beans, protein dish, salad, and some dessert). In this case the management is oriented for a cost leadership strategy (Legimai et al., 2022; Uyar et al., 2022; Wallace & Wallace, 2022). Instead, it is possible to see many dark kitchens offering hedonic foods such as snacks and desserts. In Limeira snacks were the most prevalent category, whilst in Campinas it was desserts. In this case, dark kitchen tends to be aligned to product differentiation strategy (Murray, 1988). It may be easier for small entrepreneurs to open a restaurant selling snacks or sweets, as planning, menu, and management are less complex than a restaurant. By producing fewer units, entrepreneurs can also focus on producing differentiated snacks and desserts that focus on sensory aspects.

The variables such as delivery time and user rating did not seem to show a clear pattern distinguishing between dark kitchens and standard restaurants. Delivery time seems to be related to the location of the restaurant, regardless of the type of restaurant. However, the rating depends on several factors. The iFood® application itself suggests that when rating, the user provides positive or negative aspects on the characteristics of taste, seasoning, appearance, quantity, packaging, temperature, ingredients, cooking point and wrong items, and also allows a specific rating of the delivery itself, which is not related to the restaurant but to the driver responsible for the delivery. Rating is very important to stimulate user purchase behaviour (Shah et al., 2023) and this can be even more important for small independent restaurants, such as small dark kitchens, which are more prone to failure (Nizam, 2017).

Table 3 shows the probability of occurrence of different characteristics in dark kitchens in regions closer to the central points. Delivery time seems to be less likely to be higher (or to increase) in the dark kitchens in the central buffer of the three cities studied. In Limeira, snack categories (58%) and desserts (79%) were also characteristics that were less likely to be present in dark kitchens in the central region. Dark kitchens in Limeira were more likely to prepare snacks and desserts and, as mentioned earlier, these are items that are easier to produce in small kitchens. It is possible that this type of sale is more common in home-based kitchens, which tend to be more dispersed in central points. In Campinas, increased price seems to have a higher probability (26%) of being present within a 3.4 km² radius of the central point. As mentioned above, rents tend to be more expensive in city centres, which can make goods and services offered in the area more expensive. Also, ethnic foods had a higher probability to be in the centre. Ethnic foods have greater added value and may require greater investment and skilled culinary staff (Farrer, 2020; Wessendorf & Farrer, 2021). The ethnic heritage food may face some risk factors such as 'adaptation to customer preference', 'costs of ingredients', and 'non-native origin of chef' (Almansouri et al., 2022; Arsil et al., 2022; Mawroh & Dixit, 2023). Most of the ethnic restaurants were composed of Japanese restaurants representing 5.5% of all restaurants. Finally, in São Paulo, the pizza category seems to have a lower chance (84%) of being present in the central space of 5.8km².

[Table 3]

It is important to note that Model 1 has low explanatory power. This does not invalidate the model, but shows an important urban feature. Since Limeira was the smallest city studied, the differences in distance and delivery times between dark kitchens and standard restaurants were smaller or not significant. In the models for Campinas and São Paulo, delivery time played an important role in explanatory power.

4.2. Dark kitchen models

In the manual phase of analysing the type of restaurants, several features of dark kitchens were extracted and summarised (Table 4). At this stage, the aim was not to classify dark kitchens in a quantitative fashion, but to explore the different strategies and models of these food services. Finally, answering the fourth research question (Q4), six dark kitchen models emerged from the qualitative analyses: i. independent dark kitchen, ii. shell type (hub), iii. franchises, iv. virtual kitchen in a standard restaurant (different menu), v. virtual kitchen in a standard restaurant (similar menu but with different restaurant name), and vi. home-based dark kitchen. Some models are commonly known, such as independent dark kitchens, shell-type (hubs), and franchises (John, 2021). The franchise business model has proliferated in recent years (Kang, 2019), and investment in this model underpins the idea that dark kitchens are seen as businesses with good economic potential. Franchisors must offer products and services adapted to their customers (Combs & Ketchen, 2003). In this case, franchisors benefit from lower maintenance costs of dark kitchens associated with a strong and well-known name/brand.

[Table 4]

Different models of dark kitchens were observed, such as models iv, v, and vi. This result shows that technology can create other models of food services that serve different market sectors. For example, models iv and v have different marketing stimuli. Those that have the same menus (model v) may use other names for the same restaurant to gain wider application penetration, appear more frequently as an option on the consumer's screen, or even to circumvent a particular application metric. For example, if the application lowers the profile of a restaurant due to low ratings (by not showing it as the first option in the application), adding a "new restaurant" to the application may provide new opportunities to stand out and consequently generate new sales. In contrast, a virtual kitchen in a standard restaurant (different menu) can potentially create new opportunities for the space itself. An example is self-service

restaurants (i.e., the consumer assembles their plate from the buffet on site), which often operate during lunchtime in Brazil. So it is possible to have sales in a standard restaurant at lunchtime but cover the service by using the available kitchen for other sales at other times of the day. Another interesting example is that of a standard restaurant that offers typical Brazilian dishes and has another restaurant at its address with a different name that offers only vegetarian dishes. This strategy can increase sales to an audience with special requirements, such as vegetarians.

Home-based dark kitchens (model vi) were also identified during the research. In the case of residential buildings, these restaurants may have similar characteristics to family restaurants and small businesses. Due to their characteristics, family restaurants may have increased risks related to food safety (Pereira et al., 2021). Family businesses like these restaurants may be particularly common in developing countries. Model vi evolves under difficult economic and supply-side conditions where the service profile changes, with workers moving into self-employment at times of greater employability difficulties (Gindling & Newhouse, 2014). Given that the pandemic has led to economic instability and increased unemployment (Lee & Yang, 2022), this migration out of employment and, consequently, into residential kitchens may have been encouraged. This profile shows that attention needs to be paid to this dark kitchen model, which can be a potential problem in delivering safe food for the population.

4.3 Theoretical implication

This work reveals a compelling theoretical implication. First, it is not possible to assume only one type of dark kitchen. The typology and models of dark kitchen developed by this study represents an advancement for future empirical studies on dark kitchen services. It is obvious that food business owners are adapting their services in order to reduce costs and increase profits. In this sense, it is possible that new, different models can emerge in opportune scenarios and contexts in different cultures. Future researches can empirically examine and compare our proposal and typology or extract some constructs to study the dark kitchen phenomenon in different countries or between countries.

4.4 Practical and policy implications

Several practical implications can be drawn from the results. First, the number of dark kitchens in the most popular food delivery app in Brazil is considerable (27%), and it may be even higher if we take into account the percentage of restaurants that could not be classified (7.7%). These data show the urgency of specific measures for this sector. The typology and models of dark kitchens observed in this study also highlight the importance of specific measures and policies taking into account the particularities of each model. In order to improve and support the sector, it is necessary to take into account the perspective of each of the models, which are likely to have different needs

and problems that need to be addressed. Stakeholders and policy makers need to be guided by the characteristics of each model when developing regulations.

Secondly, it could be seen that most dark kitchens offer less complex meals (i.e., snacks and desserts). This is an important feature because it can reduce the cost and complexity of operating in this type of food service. With some loss of delivery time, dark kitchens can benefit from cheaper rents in "non-central" areas. This allows them to offer more competitive and attractive prices to customers. Nevertheless, the importance of building a strong brand for dark kitchens is highlighted, as price, customer reviews and delivery time are not the only factors that consumers consider in their decision-making.

Finally, there is an important political implication. Not only were many dark kitchens located in residential areas, many of them were also located within private homes (i.e., home-based dark kitchens). This influences how health surveillance can monitor these places. Current Brazilian law does not allow any authority to enter residential premises without a warrant. In this sense, a theoretical discussion is emerging on how to give legitimacy and legality to these dark kitchens. There is a need for health surveillance to set standards and ways to monitor dark kitchens in order to be able to protect consumer health.

4.5 Limitations and future research

This study has some limitations. First, the study was conducted in the state of São Paulo. This does not necessarily represent the scenario of a country with a large land area, such as Brazil. To verify whether the results found in this study can be generalised to other regions of Brazil, more comprehensive studies need to be conducted in more locations. As the analyses conducted here only concern a single delivery application, applications with other profiles may yield different characterisation results. An example would be applications that cater to consumers based in small towns.

Finally, this study was also insufficient to assess potential risks to the food delivery app users associated with dark kitchens. Despite the hypothesis that it may be more difficult for small establishments to comply with food safety regulations, no study has yet examined food safety in dark kitchens. In this case, it is essential to distinguish between the different models of dark kitchens. For example, home-based dark kitchens are likely to face other difficulties than those operated by shells or franchises.

It is important to emphasise that this work served to understand and explore dark kitchens and provide an overview of this food service. The observations and notes taken during data collection allowed for an understanding of what might be found as a dark kitchen, but not to classify each dark kitchen. The food services were heterogeneous and in several of them it was not possible to classify due to a lack of information. It would be interesting for future research to compare the characteristics

of the different dark kitchen models described in this study. New studies need to be designed to confirm the various hypotheses put forward here.

5. Conclusions

This study is a first analysis of the presence of dark kitchens and the characterisation of this food service model in different urban centres in the State of São Paulo, Brazil. Our results demonstrated a re-distribution of restaurants, as evidenced by the different geographical distribution of dark kitchens compared to standard restaurants. In the total number of restaurants studied, 27% dark kitchens were observed, with a higher percentage in São Paulo (35.4%), a city with a greater expanse of land, economic development and population. It is estimated that the percentage of dark kitchens might be higher due to the number of restaurants that could not be classified. In several analyses of this study, dark kitchens were found to be more dispersed and distant from central points than standard restaurants, which were more concentrated in city centres. Nevertheless, it was found that there are differences in the profile of dark kitchens and standard restaurants. Dark kitchens had a lower price range and fewer reviews than standard restaurants. In addition, dark kitchens selling snacks and desserts were found to be more common in smaller cities such as Campinas and Limeira. These results differed from São Paulo, where Brazilian food were commonly sold in both dark kitchens and standard restaurants.

Furthermore, this study brings to light numerous characteristics observed in dark kitchens in a standardised manner, leading to various models of dark kitchens. It was possible to identify six different models of dark kitchens: independent dark kitchen, shell type (hub), franchises, virtual kitchen in a standard restaurant (different menu), virtual kitchen in a standard restaurant (similar menu but different name), and home-based dark kitchen.

The results of this study are important for entrepreneurs in this sector to understand the characteristics of this type of service. Moreover, the data can be used to formulate specific guidelines and regulations for dark kitchens, as they are different from standard restaurants.

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988

989 **Figure 1** – Criteria for classifying restaurants as standard, dark kitchen, or undefined.

990

991 Legend: red (high density); yellow (moderate density); blue (low density). A and B: Limeira; C and D:
992 Campinas; E and F: São Paulo.

993 **Figure 2** – Heatmaps of dark kitchens and standard restaurants of Limeira, Campinas
994 and São Paulo.

995

996

997 **Table 1.** Sample classification.

City	Standard restaurant		Dark kitchen		Undefined	
	n	%	n	%	n	%
Limeira	626	65.4	215	22.5	116	12.1
Campinas	625	70.3	217	24.4	47	5.3
São Paulo	498	59.6	295	35.3	43	5.1
Total	1749	65.2	727	27.1	206	7.7

998 DK: Dark kitchen; SR: Standard restaurant.

999

Table 2. Comparison between dark kitchens and standard restaurants considering different variables in the cities of Campinas, Limeira, and São Paulo (Brazil).

Variable	Limeira			Campinas			São Paulo		
	SR	DK	p-value	SR	DK	p-value	SR	DK	p-value
Distance from central point (mean km)	2.46	2.66	0.037	3.31	4.08	<0.001	4.62	6.21	0.001
Density in central point (number of outlets/km ²)†	123.0	43.8	-	105.3	30.3	-	61.8	13.9	-
Delivery time (mean minutes)	45.27	45.87	0.968	42.40	45.32	0.034	46.67	43.42	0.007
User rating (mean 5-point scale)	4.56	4.58	0.708	4.57	4.50	0.252	4.64	4.25	0.001
User rating count (mean n)	80.1	25.6	<0.001	132.1	68.9	<0.001	181.7	109.3	<0.001
Price range (mean 5-point scale)	1.71	1.40	0.001	1.93	1.44	0.001	2.70	2.03	0.001
Category – Type of food offered (%)*									
<i>Brazilian Food</i>	29.1	23.4	-	24.5	25.8	-	32.9	30.3	-
<i>Ethnic food</i>	6.6	4.8	-	9.8	12.4	-	15.7	23.9	-
<i>Snacks</i>	29.9	37.7	-	24.6	18.4	-	9.5	8.4	-
<i>Pizza</i>	9.2	5.2	-	6.2	5.1	-	4.7	5.2	-
<i>Desserts</i>	17.7	19.5	-	28.2	31.8	-	12.9	16.7	-
<i>Bakery and cafe</i>	3.9	2.6	-	6.7	6.5	-	7.5	0.6	-

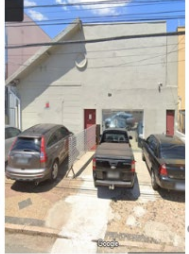
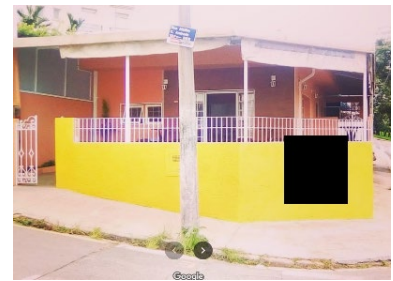
DK: Dark kitchen; SR: Standard restaurant; * percentage of column; † 5km² of range; Bold p-values are significant differences.

1005 **Table 3 – Multiple logistic regression for dark kitchens density in city centre.**

Model	Independent	OR	95% CI		R ²
Model 1 - Limeira (2.5 km ² buffer)	Delivery time (min)	0.94	0.92	0.96	0.06
	Price range (1-5)	1.58	1.08	2.31	
	Category: Snack (dummy: yes)	0.42	0.21	0.85	
	Category: Desserts (dummy: yes)	0.21	0.08	0.53	
Model 2 - Campinas (3.4 km ² buffer)	Delivery time (min)	0.92	0.91	0.93	0.27
	Price range (1-5)	1.26	1.10	1.45	
	Category: Ethnic (dummy: yes)	2.04	1.23	3.40	
Model 3 - São Paulo (5.8 km ² buffer)	Delivery time (min)	0.95	0.93	0.97	0.27
	Category: Pizza (dummy: yes)	0.16	0.04	0.62	
	User rating (1-5)	3.11	2.14	4.52	

1006 Dummy: 1= yes; 0= no; OR= Odds Ratio; 95% CI= 95% confidence interval.

1007

Model and characteristics	Example (confirmation)	Example (photo)
<i>i. Independent dark kitchen:</i> Kitchens rented by a brand exclusively for its own use, which may or may not have a storefront.	The lack of a storefront, the lack of information about the place has services in the physical space when searching through Google and social networks.	
<i>ii. Shell-type (Hub):</i> Premises are shared by more than one kitchen/restaurant. A physical space rented by multiple restaurant owners.	The storefront had a larger sign pointing to the name of the hub and other smaller signs with the logos of the restaurants selling in the area. All the restaurants mentioned on the signs had addresses in that location.	
<i>iii. Franchises:</i> Dark kitchens that have more than one outlet, with well-established social networks that can indicate the presence of this restaurant in different cities.	Restaurant has several units some with a storefront, or in dark kitchen model. It was also possible to find franchises whose restaurants operate exclusively in the dark kitchen model, as shown in the picture on the franchise website (a search bar to check if your address is in the delivery area).	  
<i>iv. Virtual kitchen in a standard restaurant (different menu):</i> Virtual kitchen is set up at the same address as a storefront restaurant but with a different name and service than the standard restaurant.	One could see the storefront of a restaurant selling Brazilian food. In the same place, another restaurant is registered that sells Italian food exclusively online (different menus).	
<i>v. Virtual kitchen in a standard restaurant (similar menu but with different restaurant name):</i> Virtual kitchen is set up at the same address as a storefront restaurant, with similar service (i.e., same type of menu) as the standard restaurant, but with a different name.	Two restaurants are registered at the same address. The menu and the category of food sold are similar, but only one of the restaurants has a frontage, the other does not have its name physically displayed.	

vi. Home-based dark kitchen: Restaurant located in a residential building.
Kitchens in residential buildings, which may be in houses, condominiums or flats.



1009 Images from Google Street View (2022).

1010