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A latent class analysis of food hygiene and handling practices among urban and peri-urban residents in Hyderabad, India

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ABSTRACT

In developing countries, food-borne diseases, attributable to lack of, or inappropriate, food hygiene and handling practices at home, are expected to increase due to a rapid growth in the consumption of fats and animal source foods. The context-specific and situational practices corresponding to underlying traits of food hygiene and handling practices for home-cooked food were investigated for a set of 662 randomly selected households in Hyderabad, India. Results indicate that about one-third of the households lack access to a refrigerator. Of those with a refrigerator, a majority (83%) had the temperature set at medium, with an actual temperature ranging from 8 to 11 °C. Results also show that smell, followed by food appearance rather than taste or labelled expiry dates were used as the main criteria for edibility. Furthermore, six indicators related to handling, storage and cooking non-vegetarian food and three indicators related to storage of the cooked food were assessed. For households with a refrigerator, the latent class analysis identified three exclusive and exhaustive subgroups of households representing the heterogeneity of handling and hygiene traits, while two subgroups were identified for households not having a refrigerator. Only a small proportion of households (12.6%) with a refrigerator were profiled as having adequate and consistent practices. Remaining subgroups revealed substantial within-group variations in terms of consistency in certain behaviors. Next, latent class modelling with covariates related to socio-demographic, socio-economic, socio-spatial variables and health or dietary outcomes showed that having higher than a primary school education, having a high percentage of food expenditure, or non-optimal refrigerator temperature were predictive of the latent class with more adequate practices. For households without a refrigerator, five covariates related to social class, age, income, and obesity distinguished the latent classes. These findings of latent trait-specific behaviors have implications for actions aiming to inform and direct behavioral change interventions on food safety practices in the developing countries.

1. Introduction

India is experiencing rapid population growth and socio-economic development including urbanization and rising household incomes. However, according to the World Health Organization (2015), India ranks as the world sub-region with the third highest estimates of food-borne Disability-Adjusted Life Years (DALYs), with diarrhea and infectious disease agents being most prominent. The economic costs associated with foodborne disease (FBD) illnesses in India amount to $15 billion per year, with China and India accounting for 71% of the total economic burden of FBD in Asia (World Bank, 2019). Available projections indicate a 60% increase in FBD illnesses in India in 2030 compared to 2011 with younger children under the age of five expected to be disproportionately affected (Smeets Kristkova, Grace, and Kuiper, 2017). This development is expected to lead to a socio-spatial divide in that higher income and richer urban households will become more affected compared to other rural or poor urban households. This is because income growth is projected to increase consumption of food, especially fats and animal sourced foods (Hoffman, Moser, and Saak, 2019) that are typical causes of FBD at the same time as further urbanization increases transmissions of FBD through human contact and contaminated foods. Currently, animal source foods amounts to 21% of

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FBD in India (World Bank, 2019).

Food safety hazards and FBD potentially emanate and accumulate from sources of contamination along the pathway from production to consumption. Existing research, predominately from developed countries, has identified improper food hygiene and handling at home as the weakest link in the food chain (e.g. Brennan, McCarthy, & Ritson, 2007). Consumer-related FBD hazards are especially attributable to lack of, or inappropriate, food hygiene and handling practices (FHHPs) at home such as storage and cross contamination as well as chilling, heating, and cleaning (Azevedo, Albano, Silva, & Teixeira, 2014; Grace, 2017; Redmond & Griffith, 2003). In developing countries, practicing safe food hygiene and handling at home is further challenged by climate related issues such as potential lack of access to refrigeration and running water as well as through further contamination pressure through a range of background risk factors such as those pertaining to the physical environment (e.g. dust, dirt, contact with livestock, etc.) (Hoffmann, Moser, & Saak, 2019). Several studies are available on food safety risks associated with food handling, particularly chicken, other meat and eggs (see Hessel et al., 2019). However, existing research is still limited as regards geographical focus with little representation from low and middle-income countries. There is also a lack of assessment regarding how FHHPs differ across subgroups of individuals.

Available reviews of previous research on domestic FHHPs indicate the influence of psychological and health status as well as socio-demographic factors such as age, gender, level of education, income, location, culture, and race as factors contributing to explain domestic food safety behavior (Al-Sakkaf, 2015; Young et al., 2017). These reviews also identified only four studies (Brennan et al., 2007; Kennedy et al., 2005, 2008; McCarthy et al., 2007) that used clustering based on Principal Component Analysis to segment consumers according to demographic and socio-economic characteristics with the aim to identify high-risk groups to which targeted food safety-oriented behavioral change interventions could be tailored.

Given the importance of FHHPs at home in the prevention of FBD, an alternative approach would be to ask whether there exist context-specific and situational practices corresponding to underlying traits of such behaviors. Notably, while FHHPs at home are observable through the use of certain indicators, the underlying traits of such behaviors cannot be observed directly. In this study, we focus on such practices that relate to handling, hygiene, and storage of cooked food but exclude practices related to non-cooked food such as fruit and vegetables as we expect relevant practices to differ. Moreover, in Telangana, India, where the study was conducted, the majority of households consume small quantities of vegetables due to cultural reasons (Kumar et al., 2017). However, the growing recognition of vegetables as important components of a healthy diet is driving increased consumption, particularly among the upper-middle and higher-income groups. To our knowledge, no previous study has examined the underlying traits of food hygiene and handling practices at home, and how these then relates to socio-economic and health characteristics of the individuals. Rather than doing the segmentation based on observable characteristics of individuals, an identification through latent trait-specific behaviors has the potential to inform and direct behavior change interventions. Three research questions were addressed:

1. What types of domestic food storage facilities are used, and what refrigerator temperature do different households maintain (when applicable)?
2. Are there underlying (i.e. latent) exclusive and exhaustive subgroups of households in terms of (i.e. traits of) FHHPs at home in the sense of latent classes that adequately represent the heterogeneity of such traits. If so, what are distinguishing practices within the subgroups and how large are these groups?
3. Are socio-demographic variables, socio-economic, or socio-spatial variables, or alternatively, health or dietary outcome variables predicative of latent food hygiene and handling traits?

2. Method

2.1. Study area and participants

Located in the Telangana state of Southern India, the city of Hyderabad is the sixth largest metropolis in the country. The population is growing at 8% per annum and rapid economic development has increased the city's population to around 12 million from 7.6 million in 2011 (Census, 2011) with a density of 18,000 per square kilometer.

A remote sensing analysis using multi-sensor satellite data identified four study areas, consisting of two peri-urban and two urban areas with grid sizes of 10 × 10 km each, characterized by the highest intensity of urban expansion (Krishna Gumma et al., 2017). The location of the study areas is given in Fig. 1.

Local government officials provided a list of households within the study areas for which there was at least one adolescent and/or a child between 3 and 5 years of age. Based on probability proportion to size sampling, 662 households were selected randomly from the list of households. Population data for each of the 14 mandals (i.e. sub-units within administrative district) within the study areas was collected from the District Census Handbook 2011 showing a total population of 1,248,364 (urban = 44.6%, peri-urban = 55.41%).

After approval from the Greater Hyderabad Municipal Corporation (GHMC), data were collected during the period October 2018–February 2019 using household interviews in Hyderabad (in local language) by six enumerators (three male, three female) using tablets for data entry. The questionnaire was pre-tested in non-study locations in Hyderabad identified to have similar population density characteristics as the study locations. Enumerators were trained by researchers from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) on the data collection procedures and protocols using Computer-assisted personal interviewing (CAPI) methodology. A photocopy of the approval letters was provided to the enumerators to carry into the field and be shown if asked for by the respondents. The data collection was then supervised by ICRISAT staff with responsibilities for daily data quality control. Within each household, the person selected to be interviewed was the adult doing the cooking and food preparation. Adults for this study are defined as individuals aged 20 to 65. Informed written consent from the participants as well as photo consent of the participants were taken before data collection started. Respondents completing the survey in the current study were given a small incentive (a useful household item), amounting to about US $1.50, for their time in completing the survey.

2.2. Measures

2.2.1. Domestic food hygiene handling practices

In total, nine indicators of FHHPs were included in this study (see Table 3 in Section 3). This selection was based on the '5 keys to safer food practices' (keep clean, separate raw and cooked, cook thoroughly, keep food at safe temperatures, and use safe water and raw materials) introduced by WHO (2006). Indicators were selected so that they would be relevant for most types of households. Of the nine indicators, six were related to handling, storage and cooking non-vegetarian food and three were related to storage of the cooked food. Three indicators related to use of a refrigerator were included even though we did not anticipate that every households would have a refrigerator.

Handling of raw chicken meat and other meats and fish was kept separate in the questionnaire to account for the differences in the food preparation and cooking methods. Raw chicken is typically washed thoroughly with turmeric and all the water is drained before cooking. Hence raw chicken meat is touched with hands before cooking. Raw lamb meat on the other hand is not washed before cooking, it may just be rinsed in water and the water drained off. So raw lamb meat is not physically touched during the washing process. Fish is usually bought home after it has been cleaned and cut in the market. Once fish is

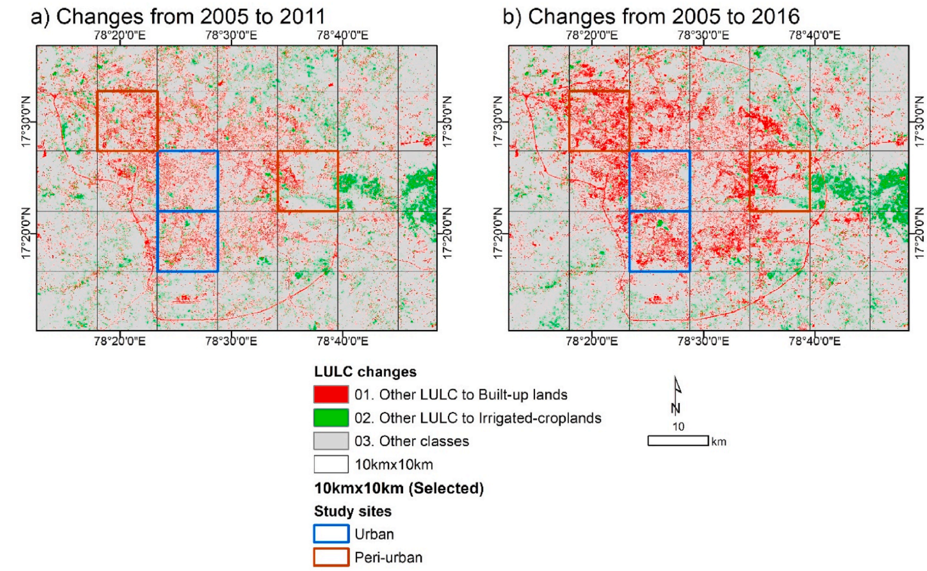

Fig. 1. Study area Hyderabad with selected grids (blue and brown squares) for study sites. (print in color). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

purchased, it gets cleaned by fish cleaners who exist beside fish vendors in the market who remove fins, gills, internal organs and waste for a charge. Hence, fish is just rinsed at home and this usually does not involve touching the pieces while washing.

The nine indicators were measured using a five-item range (1 = always; 5 = never) and a last option of "no response". The assessment also indicates the level of food safety knowledge food safety knowledge level of the respondent in relation to existing 'best-practice' recommendations. The correct response for indicators 1 to 4 is "always", and is "never" for indicators 5 to 9.

2.2.2. *Food storage and refrigerator temperature*

Different storage alternatives were included in the survey to assess the safe practices for storage of food, especially cooked food. The cooling level of the refrigerator used by the household was identified using three categories (low, medium and high) (see Section 3.2). A dummy coding with 1 = high cooling, and 0 = medium or low was used. Actual temperature was assessed using a thermometer specifically designed to measure refrigerators' temperature.

2.2.3. *Predictors of traits for domestic food hygiene and handling practices*

Several characteristics of households were selected as potential predictors of the unobserved patterns of FHHPs among individuals. These covariates were subdivided into three distinct groups.

One group contains three basic socio-demographic variables, namely: age, highest level of education attainment and social group. Age was measured using three categories and coded with two dummy variables corresponding to (a) age 30–36 = 1, otherwise = 0 and (b) age ≥37 = 1; otherwise = 0, meaning that the reference group is of an age below 30. The highest level of education size was dummy coded, with 1 representing respondents with secondary school or higher, and 0 representing those with none or primary education. And, so for social group (caste) (backward or forward caste (higher caste) = 1, scheduled caste or tribes (lower caste) = 0).

A second group contains socio-economic variables. Household size was dummy coded indicating five or more = 1 or, four or less = 0. Residence area was coded as urban = 1, peri-urban = 0. Annual household income coded with two categories corresponding to higher (=1, >176,000 INR) or low (≤176,000 INR) income. Lastly, the proportion of food expenditure to total consumption expenditure was coded in two categories with dummy variables corresponding to medium proportion 26–35% = 1, otherwise = 0 and high proportion> 36% = 1; otherwise = 0 meaning that the reference group are households with a proportion lower than 26%.

Finally, health outcome was assessed by body mass index (BMI), and dietary preferences were included as a third type of covariate. It has been documented that rising income is associated with potential negative health outcomes due to increases in BMI (e.g. Ren, Li, & Wang, 2019). The weight and height of the respondents were measured using standardized SEACA weight and height scales. Using the weight and height the individual BMI was calculated and coded into four categories corresponding to underweight (=1, BMI<18.5), normal (= 2, 18.5<BMI<24.9), overweight (=3, 25<BMI<29), or obese (=4, BMI≥ 30). The BMI data were dummy-coded with three variables using the normal category as reference. Furthermore, whether the participant is a vegetarian (=1) or not (= 0) was used as a dichotomous variable.

2.3. *Analytical strategy*

In absence of theory, the number of subgroups of people with different domestic FHHPs is unknown. Latent Class Analysis (LCA) is appropriate to characterize distinct subgroups when the indicator measures are categorical. Therefore, following Lanza, Collins, Lemmon, and Schafer (2007), a sequence of latent class (LC) models were initially fitted to identify the appropriate number of latent classes that adequately represent the heterogeneity in domestic FHHPs. In particular, the approach taken by Nylund et al., (2007); Asparouhov and Muthén, 2012 guided the analyses of the number of latent classes. First, the best log-likelihood for the *k-1* and *k* number of classes was determined using twenty initial and four final iterations of the LC models, respectively. Second, the number of random starting value perturbation was increased to 100 and 20, respectively, to test the replicability of the best log likelihood from the first step. Third, using the optimal seed from step two, the Vuong-Lo-Mendell-Rubin and the adjusted Lo-Mendell-Rubin likelihood ratio tests were used as the 'stopping rule' for whether the *k-1* class model was to be rejected in favor of the *k* class model. For each model, the local independence assumption of LCA was evaluated using the standardized Pearson residuals computed as (O-E)/[sqrt(E)*sqrt(1-E/n)] for each two-way cross-tabulation, where O and E are the observed and expected (model estimated) quantities for a pattern in the categorical data, and the numerator expresses the degrees of freedom. Following the recommendation from Haberman (1973), standardized residuals set at z >|1.96| was used as the threshold to indicate that the assumption of conditional local independence was unmet.

Next, because the inclusion of covariates may influence the optimal latent class solution, the baseline LC model was firstly identified, then covariates were incorporated separately in the second set of LC analyses to examine their predictive power in explaining latent class membership. This is established as an acceptable approach, if the entropy is high (>0.8) and simplifies the interpretation of the effect of the covariate on class membership (Clark & Muthén, 2009). Furthermore, for each latent class we examined the logistic regression odd ratio results for each covariate. In each regression, the reference category was altered to test the influence of each covariate on each latent class, respectively. For this study, all LCA models were estimated using Mplus 8.3 software (Muthén & Muthén, 1998-2017).

3. Results

3.1. Socio-demographic characteristics

Table 1 presents the summary characteristics of households with and without a refrigerator. All respondents were female with a mean age of 33.3 years (SD = 5.98, min = 20, max = 65), and with roles as spouse (99.2%) or household head (0.8%). Household size was relatively homogeneous (M = 4.86, SD = 1.20), whereas there was more variation in the annual household income (M = 218,476INR, SD = 167,402INR). Levels of education also varied across the full sample (no school = 28.9%, primary school = 11.4%, secondary school = 42.3%, university or college = 7.2%, and post-graduate = 2.4%), with data on education missing for 0.8% of the full sample. Moreover, ethnographically, respondents were distributed over scheduled tribes (3.2%), scheduled caste (34.3%), backward caste (54.8%), and the forward caste (7.7%).

Table 1
Socio-demographic characteristics of respondents (n = 662).

Characteristics	Description	Household with refrigerator (n = 435)	Household without refrigerator (n = 227)
		Proportion (%)	Proportion (%)
Age (years)	20–30	22.5	27.3
	30–36	52.0	44.1
	37–65	25.5	28.6
Educational level	No or primary school	29.4	60.8
	Secondary school, or more	69.9	39.8
	Missing data	0.7	–
Household size	4 or less	46.7	42.3
	5 or more	53.3	57.7
Household income[a]	176,000 INR per year or less	37.9	56.8
	>176,000 INR per year	62.1	43.2
Proportion of food expenditure	0–25%	15.2	13.2
	26–35%	50.6	48.9
	36–75%	34.3	37.9
Social group	Scheduled tribes or caste	31.3	49.3
	Backward or Forward caste	68.7	50.7
Location of HH	Peri-urban	55.2	57.7
	Urban	44.8	42.3
Vegetarian	No	98.6	96.0
	Yes	1.4	4.0
Body-Mass Index (BMI)[b]	Underweight (BMI<18.5)	6.9	12.8
	Normal (18.5<BMI<24.9)	39.8	44.9
	Overweight/ 25<BMI<29.0)	34.0	32.2
	Obese (BMI≥30)	17.5	7.9
	Missing	1.8	2.2

[a] At the time of the study 1 USD = INR 68.
[b] BMI refers to the respondent.

3.2. Food storage and edibility criteria

Table 2 presents the results regarding food storage and the main edibility criteria adopted by the respondents. Concerning food storage, almost two-thirds of them (n = 435) reported that they used a refrigerator as the first means to store food. In total, four demographic measures significantly differed between respondents depending on their ownership of a refrigerator, or not. First, there was a statistically significant association between having a refrigerator and the educational level of the respondent ($\chi(1) = 60.8$, $p < 0.001$, n = 658). In particular, a larger percentage of respondents with higher levels of formal school education had a refrigerator (304 out of 435). The opposite was found for respondents with low formal education where 138 out of 227 did not have a refrigerator. Second, household income was also significant as predictor for having a refrigerator ($\chi(1) = 21.6$, $p < 0.001$). Third, there was support for an association between social group and using a refrigerator ($\chi(1) = 20.8$, $p < 0.001$). Fourth, the age of the respondent was, however, only partly significant in explaining use of a refrigerator, with support for respondents of age 30–36 being more likely to have a refrigerator as compared to younger respondents ($\chi(1) = 3.73$, $p = 0.054$, n = 662). However, there was no such support comparing the older respondents (≥37 years) with the youngest (($\chi(1) = 0.74$, $p = 0.39$, n = 662).

Furthermore, there was no support for an association between having a refrigerator and household size ($\chi(1) = 0.93$, $p = 0.283$, n = 662), for type of residence area ($\chi(1) = 0.39$, $p = 0.532$, n = 662)., for household income ($\chi(1) = 0.27$, $p = 0.602$, n = 662), or for the proportion of food expenditure (<25%: $\chi(1) = 0.46$, $p = 0.497$; 26–35%: $\chi(1) = 0.17$, $p = 0.682$; >36%: $\chi(1) = 0.86$, $p = 0.354$; n = 662).

Although a majority of the respondents reported that food appearance or smell is used as edibility criterion, there was support for a relatively weak significant statistical association to social group ($\chi(9) = 14.84$, $p = 0.096$, n = 662). There was no significant association between edibility criteria and household size ($\chi(3) = 3.78$, $p = 0.286$, n = 662), household income ($\chi(3) = 0.47$, $p = 0.925$, n = 662), location of the household ($\chi(3) = 2.05$, $p = 0.561$, n = 662), or educational level of respondents ($\chi(15) = 19.35$, $p = 0.198$, n = 657). Finally, there were no significant differences in edibility criteria between households with and without a refrigerator ($\chi(3) = 3.34$, $p = 0.342$, n = 662).

The cooling setting and temperature of the refrigerator were recorded for those 435 households (65.7% out of 662) who used a refrigerator as their main means of food storage. A majority (83%) had the temperature set at medium with an actual temperature ranging from 8 to 11 °C. A smaller percentage of households (10.8%) had the cooling set at high (actual temperature ranging from 0 to 7 °C, or had the cooling set at low (12° and above) (3%). Data was missing for 14 households (3.2%). There were no significant differences in edibility criteria between households with cooling set at high and households with other temperature settings ($\chi(3) = 1.50$, $p = 0.682$, n = 435).

Table 2
Food storage and criteria for edibility (n = 662).

Main means of food storage	Proportion (%)	Main edibility criteria	Proportion (%)
Plastic[a]	17.1	Appearance	34.9
Floor or on earth	5.1	Expiry date	0.3
Shelf	6.0	Smell	56.9
Refrigerator	66.6	Taste	7.9
Other	2.6		

[a] Includes plastic cover, container, bowls or bags.

Table 3
Descriptive statistics for domestic food hygiene and handling practices (n = 662, Hyderabad, India). (%).

Practice/Indicator	Refrige-rator or not	Always	Most of the time	Some-times	Rarely	Never	No response
1. Washing your hands after touching raw chicken meat	Yes	98.2	1.1	0.2	0	0	0.5
	No	97.8	1.8	0	0	0	0.5
2. Washing your hands after touching raw meats or fish	Yes	62.1	27.1	9.9	0.5	0	0.5
	No	75.8	15.0	8.4	0.4	0	0.4
3. Always using separate cutting boards/knives for raw chicken meat	Yes	24.1	14.7	17.9	16.6	26.0	0.7
	No	29.5	11.0	12.3	16.7	30.0	0.4
4. Rinsing boards/knives/containers used for raw chicken before using them for other food	Yes	43.7	10.1	11.7	14.3	19.8	0.5
	No	45.8	10.1	13.7	12.8	17.2	0.4
5. Leaving cold food out of the refrigerator for more than 4 h[a]	Yes	15.4	14.7	33.6	24.1	12.2	0
	No	0	0	0	0	0	100
6. Putting cooked food back into the same containers used to store raw vegetables/ raw meats without washing them first[a]	Yes	4.6	7.1	5.5	4.4	77.2	1.1
	No	2.6	3.5	3.1	4.0	85.5	1.3
7. Pouring marinades that contained raw meat over cooked meat[a]	Yes	16.3	14.9	32.0	10.1	22.3	4.4
	No	9.7	11.9	26.4	19.8	28.8	4.0
8. Leaving hot foods at room temperature for more than 4 h[a]	Yes	35.9	22.5	26.2	14.5	0.9	0
	No	100	0	0	0	0	0
9. Defrosting frozen foods outside the refrigerator[a]	Yes	12.4	14.9	33.3	20.5	18.9	0
	No	0	0	0	0	0	100

[a] Questions 5–9 were reversely coded for the analysis.

3.3. *Identification of domestic food hygiene and handling practices*

Table 3 presents the summary statistics for all indicators of FHHPs for households with and without a refrigerator, respectively. Notably, handwashing after handling of chicken meat was almost unanimously adopted by the households in the sample. Findings also indicate that the majority of the households have adopted safer practices in relation to handwashing after contact with other meats and fish as well as in using separate containers or vessels for cooked meat and storage of meats. Findings for rinsing of utensils related to handling of raw chicken meat were similar across different types of households but not as pronounced as for handwashing or use of separate vessels. Moreover, the responses relating to leaving hot food at room temperature for extended periods were unanimous for households without a refrigerator. Findings for the remaining indicator measures were more heterogeneous within, as well as between, the two groups of households. These findings provide preliminary results of little consistency in adherence to safe FHHPs.

3.4. *Latent class analysis*

The characteristics of food handling practices from Table 3 were used as indicator measures to evaluate the potential of underlying traits of domestic food hygiene and handling behavior. The analysis was done separately for households with and without a refrigerator, respectively, because there were two practices that did not apply to households without a refrigerator (i.e. practices 5 and 9). In addition, households without a refrigerator did not have an alternative means for preserving or cooling hot food (i.e. practice 8). Moreover, the practice 1 of 'washing hands after touching raw chicken meat' was not included in the LC analyses as the full adoption of this practice would not contribute to the identification of underlying traits relating to FHHPs.

Table 4 presents the goodness-of-fit criteria for the sequence of unadjusted models (i.e. without covariates) based on the number of identified classes. For households with a refrigerator, inspection of the model selection criteria suggests that a 3-class model is appropriate for the identification of the most likely class membership, while a 2-class model is appropriate for households without a refrigerator. The entropy measure (>0.8) for both types of households suggests high accuracy in the classification.

3.4.1. *Typology of domestic food hygiene and handling practices for households with a refrigerator*

For households within this sub-sample, the LCA indicates that there are three unique latent classes of traits within the data (see Table 5). Each column of Table 5 shows the probability of membership for each class, as well as the item-response probabilities for endorsing each categorical indicator response. The first class has been labelled *More Hygiene and Handling Oriented* due to actions taken by class members to reduce risks related to food hygiene and handling, although with exceptions for indicators 7 and 8. The *More Hygiene and Handling Oriented* class comprises only 12.6% of all households within this sub-sample. As a whole, member households of this class also showed high consistency in their behaviors.

Due to the tendency to adhere to safer hygiene practices, Class 2, which made up 34.3% of the sub-sample, was labelled *Some Hygiene but Less Handling Oriented,* differs substantively from Class 1, particularly in

Table 4
LCA fit indices for potential class solutions for domestic food hygiene and handling practices (unadjusted for covariates).

	LCA 1: Households with a refrigerator (n = 432)				LCA 2: Households without a refrigerator (n = 225)		
Number of classes	1	2	3	4	1	2	3
Log-likelihood (LL)	−4604	−4394	−4189	−4093	−1290	−1216	−1184
# parameters	31	63	95	127	19	39	59
Share of BVR >|1.96|	23.5	15.2	6.6	6.8	15.2	6.08	3.04
BIC(LL)	9396	9171	8954	8978	2684	2644	2687
AIC(LL)	9270	8915	8568	8462	2619	2510	2486
p-value VLMR LRT	NA	0.0011	0.0001	0.711	NA	<0.001	0.962
p-value LMR adj LRT	NA	0.0011	0.0001	0.712	NA	<0.001	0.962
Entropy	NA	0.777	0.877	0.864	NA	0.952	0.882

Note: BVR = standardized bivariate residuals for two-way cross-tabulations (665 in LCA 1, 230 in LCA 2), BIC = Bayesian Information Criterion, AIC = Akaike Information Criterion, VLMR = Vuong-Lo-Mendell-Rubin Likelihood ratio test (LRT) for *k-1* (H0) vs. *k* classes (Vuong, 1989), LMR = Lo-Mendell-Rubin adjusted LTR test (Lo, Mendell, & Rubin, 2001).

Table 5
Item-response probabilities for latent class traits given type of main food storage (unadjusted for covariates).

Item[a]	Category	Households with refrigerator (n = 442)			Households without refrigerator (n = 226)	
		Class 1 (12.6%)	Class 2 (34.3%)	Class 3 (53.1%)	Class 1 (24.8%)	Class 2 (75.2%)
2. Wash your hands after touching raw chicken meat.	Always	**0.957**	**0.232**	**0.803**	0.049	**0.994**
	Most of the time	0.043	**0.543**	**0.146**	**0.610**	0.000
	Sometimes	0.000	**0.212**	**0.051**	**0.341**	0.000
	Rarely	0.000	0.014	0.000	0.000	0.006
	Never	NA	NA	NA	NA	NA
3. Always use separate cutting boards/knives for raw chicken meat.	Always	**0.735**	**0.133**	**0.196**	**0.149**	**0.347**
	Most of the time	**0.225**	**0.194**	**0.103**	**0.225**	**0.074**
	Sometimes	0.040	**0.341**	**0.107**	**0.259**	**0.080**
	Rarely	0.000	**0.151**	**0.218**	0.037	**0.212**
	Never	0.000	**0.183**	**0.376**	**0.330**	**0.287**
4. Rinse boards/knives/containers used for raw chicken before using them for other food.	Always	**0.889**	**0.378**	**0.369**	**0.186**	**0.547**
	Most of the time	**0.074**	**0.197**	0.048**	**0.222**	**0.063**
	Sometimes	0.000	**0.184**	**0.104**	0.153**	**0.133**
	Rarely	0.000	**0.151**	**0.174**	0.146**	**0.123**
	Never	0.037	0.090**	**0.305**	**0.294**	**0.134**
5. Leave cold food out of the fridge for more than 4 h.	Never	**0.810**	0.045*	0.009		
	Rarely	0.000	**0.199**	**0.329**		
	Sometimes	0.068	**0.201**	**0.491**		
	Most of the time	0.016	**0.243**	**0.110**		
	Always	0.107	**0.312**	0.061**		
6. Putting cooked food back into the same containers used to store raw vegetables/raw meats without washing them first.	Never	**0.964**	**0.454**	**0.946**	**0.553**	**0.967**
	Rarely	0.036	0.073**	0.028**	0.093**	0.023**
	Sometimes	0.000	**0.129**	0.023*	0.128**	0.000
	Most of the time	0.000	**0.212**	0.000	0.146**	0.000
	Always	0.000	**0.132**	0.003	0.079**	0.010
7. Pour marinades that contained raw meat over cooked meat.	Never	0.060	0.047**	**0.388**	0.038	**0.377**
	Rarely	0.083**	0.105**	**0.113**	**0.196**	**0.211**
	Sometimes	0.118**	**0.381**	**0.351**	**0.330**	**0.258**
	Most of the time	0.134**	**0.264**	**0.094**	**0.271**	**0.074**
	Always	**0.605**	**0.202**	0.054**	**0.164**	**0.080**
8. Leave hot foods at room temperature for more than 4 h.	Never	0.018	0.000	0.013*		
	Rarely	0.000	0.035*	**0.252**		
	Sometimes	0.042	**0.113**	**0.409**		
	Most of the time	0.006	**0.256**	**0.256**		
	Always	**0.934**	**0.595**	0.069*		
9. Defrost frozen foods outside the fridge.	Never	**0.839**	0.000	**0.153**		
	Rarely	0.080	0.158**	**0.267**		
	Sometimes	0.082**	**0.226**	**0.467**		
	Most of the time	0.000	**0.276**	**0.101**		
	Always	0.000	**0.340**	0.012		

[a] Item 1 is not included (see section 3.4). Bold p < 0.001, **p < 0.05, *p < 0.1. NA=Not available.

the consistency of the FHHPs. Similar to Class 1, households in Class 2 put greater emphasis on safety-oriented practices related to handwashing and cleaning of utensils. These households also shared similarities in relation to unsafe practices related to marinades and chilling, although these practices were more heterogeneous in Class 2. In contrast to Class 1, households in Class 2 predominately defrosted food outside of the refrigerator. However, there was a bi-polar divide within Class 2 in terms of re-use of containers for cooked meats (indicator 6). Moreover, there was little consistency within Class 2 for the practice of using separate knives for raw chicken meat (indicator 3).

In contrast to the previous two classes, Class 3 of the households showed better adherence to safer practices related to re-use of marinades and for chilling of food. They also showed more of a bi-polar divide in terms of rinsing of knives and plates or in using separate knives for chicken meat. However, the majority of households within this class rarely or never rinse these utensils before using them for other food. Furthermore, Class 3 exhibited more appropriate practices for handwashing as compared to Class 2 but less so relative to Class 1. There were better practices to avoid storing cold food at room temperature, or chilling of food, in Class 3 as compared to Class 2 but these practices were not as adequate as for the *More Hygiene and Handling Oriented* class. Therefore, this group, which made up the majority (53.1%) of the households with access to a refrigerator, was labelled *More Handling but Less Hygiene Oriented*.

3.4.2. *Typology of domestic food hygiene and handling practices for households without a refrigerator*

Two groups of traits relating to FHHPs were found within the data for households without a refrigerator. Class 1 (24.8%) exhibited lack of adherence to strict practices for handwashing, and in re-use of marinades. As regards using separate knives, as well as in rinsing of utensils, Class 1 households exhibited strong heterogeneity in practices. The re-use of containers for cooked meat were also heterogeneous but a majority of households in this class adhered to safer practices. Given that this group appears to display little consistency in safer FHHPs, Class 1 was labelled *Less Consistent and More Exposed*.

The second class made up the vast majority of households without a refrigerator (75.2%) who were characterized by safe practices for handwashing and for re-use of containers for cooked meats. However, while most of the group had safer practices for rinsing of utensils and in re-use of marinades, there was more heterogeneity in these practices. Furthermore, this group was split in that a majority of the households had unsafe practices for keeping separate utensils for handling of chicken meat. Therefore, Class 2 households were labelled *Mixed Practices.*

3.4.3. Logistic regression odds ratio results for covariates

For households with a refrigerator only two covariates were effective in distinguishing the latent classes. First, respondents with higher than primary education were less likely to belong to Class 2 (Odds Ratio (OR) = 0.394, $p < 0.001$) and Class 3 (OR = 0.467, p = 0.006) than Class 1. Second, households allocating a higher percentage of their total expenditure to food items (36–75%) were more likely to be part of Class 1 relative to Class 3 (OR = 2.78, p = 0.069). Moreover, having higher food expenditure reduced the likelihood that a household would belong to Class 2 (OR = 0.599, p = 0.06), or to Class 3 (OR = 0.36, $p < 0.001$) relative to Class 1. Furthermore, having higher food expenditure made it less likely to be in Class 3 relative to Class 2 although this effect was not strongly supported by the data (OR = 0.601, p = 0.07).

Although only a minority of the households had the refrigerator set to high cooling, the findings showed that this was less likely within Class 1 (OR = 0.136, $p < 0.001$) but slightly more likely within Class 3 (OR = 1.009, p = 0.032) compared to Class 2.

For households without a refrigerator, five covariates distinguished the latent classes. First, belonging to the upper caste rather than to the lower castes was less likely in Class 1 relative to the larger Class 2 (OR = 0.466, p = 0.001). Findings also support that respondents within the age group of 30–36 were less likely to be in Class 1 than in Class 2 (OR = 0.546, p = 0.014). In addition, older respondents (>37) were less likely to be in Class 2 than Class 1 (OR = 0.53, p = 0.008.). Findings also support that households with a higher income were less likely to belong to Class 2 as compared to Class 1 (OR = 0.541, p = 0.007). Finally, being obese made it less likely to belong to Class 1 relative to Class 2 (OR = 0.324, p = 0.003).

4. Discussion

Over the next decade, foodborne disease (FBD illnesses in India are projected to increase rapidly due to urbanization, income growth and associated changes in food consumption behavior. The primary aim of the current study was to explore whether there exist context-specific and situational domestic food hygiene and handling practices (FHHPs related to meat-based food corresponding to underlying (i.e. latent) traits of individuals. Specifically, the study was designed to explore three related aspects of domestic FPPHs. First, as control over the cold chain is critical for managing the safety and quality of perishable food, the study identified the types of domestic food storage used and the refrigerators' temperature profiles. Second, and as a specific aim, the study sought to identify underlying types (i.e. latent classes) of domestic FHHPs and the distinguishing practices and percentages of these types. Lastly, the study aimed to explore whether socio-economic, socio-spatial variables or health and dietary outcomes are predictive of FHHPs.

The first result indicates that about one-third of the households sampled in this study lack access to a refrigerator. Predominantly, these households instead use plastic covers, containers or bags for food storage. Domestic control of cold storage and storage time of food are widely recognised as having a major influence on food quality and safety, especially for foods such as meat (e.g. James, Evans, & James, 2008). Therefore, the findings with regard to the lack of proper storage indicate that for a substantial proportion of the Hyderabad population, the domestic environment is a major setting for FBDs outbreaks. Furthermore, the findings from the present study suggest that key socio-economic characteristics of the household contribute to explaining the exposure to FBDs through lack of refrigeration. In particular, lack of access to adequate cold storage is driven by lower educational and income levels, by belonging to lower social classes (i.e. castes), or by being younger (below 30) or older (above 37). These results are consistent with a study by Rathi, Chunekar, and Kadav (2012) using National Sample Survey Office data showing that refrigerators at that time were luxury goods for Indian households and most of the poor or low-income households could not afford to buy this appliance. The cost of the refrigerator, home space and additional costs for electricity are still expected to be limiting factors for the poor urban households to have a good cold chain at home to preserve the food. Therefore, it is important to develop and promote low cost cooling appliances that poor households with less home space could afford to buy. Proper cool storage is also a cultural issue since people in India typically do not store cooked food in the refrigerator for more than a day.

Results also show that smell and then food appearance rather than taste or labelled expiry date were used as the main criteria for edibility. This is reasonable given that the majority of Indian households cook hot food at home rather than purchase packaged or preserved food from stores. Moreover, edibility criteria were invariant as regards having a refrigerator or not and also as regards whether the refrigerator was set to high cooling or not. This finding could be indicative of lack of knowledge, or awareness, of the correct temperature for cold storage of perishable food, which then would corroborate existing findings in the literature (e.g. Jevšnik, Hlebec, & Raspor, 2008). The edibility criteria relate to the decisions, or checks, being made while being exposed to health background risks. Using smell and appearance can then be considered as prudent behaviors in relation to risk (i.e. an aversion to downside risk (Menezes, Geiss, & Tressler, 1980). The findings of the present study are then unexpected as previous studies have shown that risk perception functions as a predictor of intentions to perform safer food handling practices (Mullan, Wong, & Kothe, 2013). It would then have been reasonable that the edibility criteria would be adjusted depending on the severity, or awareness, of health risks. Households without a refrigerator or households with higher storage temperatures should be expected to be even more prone to use smell and appearance to discriminate food before consumption. Although there is little available evidence in the literature regarding the extent of these adjustments, such research would require observations of decisions in relation to an exogenous change in levels of background risks.

Second, unlike the existing literature, which adopts segmentation approaches based on observable characteristics of individuals or households to investigate domestic FHHPs, this study used a LCA approach. As a main finding, the results showed that there are between-class variations in the sense of latent classes that adequately represent the heterogeneity in food hygiene and handling behaviors. Furthermore, there were also between-class differences in the coherence of FHHPs, implying that the focus on hygiene and handling was different. Some household groups (classes) revealed more coherence in addressing appropriate practices of more aspects of hygiene or handling, while other groups with less coherence had more mixed behaviors. Moreover, results also showed substantial within-group variations in terms of consistency of certain practices.

Notably, the latent classification in the form of exclusive and exhaustive subgroups of individuals was found to be more differentiated for households with a refrigerator, while there was less between-class variation among households without a refrigerator. For households with a refrigerator, the between-class variations were due to different balances given to practices related to food hygiene versus handling. The smallest class (12%) revealed more balanced and more safety-oriented behaviors but was still found to have inappropriate, and therefore less coherent behaviors concerning use of marinades for meat and for chilling of food. The second group was profiled more towards hygiene than to handling, while the third and largest group, constituting 53% of the households, was classified as more handling and less hygiene oriented. With regard to households without a refrigerator, the between-group variation was more driven by differences in coherencies of practices rather than by substantial differences in the balance between hygiene and handling. Interestingly, the largest class (75%) of households without a refrigerator was more coherent and more profiled towards having safer practices compared to the other class.

Third, the LCA also revealed substantial within-group variations in terms of consistency in certain behaviors (within-class heterogeneity). For households with a refrigerator, this type of variation in FHHPs was substantial for the two larger latent classes. Furthermore, the pattern of variation was distinctively different between the two classes in that the variation among the second class (denoted as *Some Hygiene but Less Handling Oriented*) was drawn towards practices that should increase the exposure to FBDs. For the larger class, the variation was drawn more towards less risky practices. For both classes, and similar for households without a refrigerator, there was, however, a more uniform variation in lack of adherence to adequate practices for hygiene practices related to handling of chicken meat. These findings suggest the need of targeted educational and behavioral change interventions to strengthen the capacity and awareness of households especially for how to handle meat, and in particular chicken meat. However, there is a further need to direct efforts towards households within the second class. These households can be seen to have misdirected food safety practices, together with substantial variations in these practices.

Fourth, the results indicate that having a higher level of education (more than primary school) and having a high proportion of food expenditure made it more likely for households with a refrigerator to belong to the latent class with the most food hygiene and handling oriented traits. Specifically, the finding that higher education makes it more likely to adopt safer practices corroborates findings for developing countries within the health literature showing that basic education improves population health (Oh, 2019). An explanation of this finding is that higher levels of education enable individuals to make more informed choices. It is notable then that the latent class with safer practices was quite small (12%), meaning that individuals with higher formal education also appeared in the latent classes with more varying food safety behaviours. This finding accords with the findings of previous studies concerning the discrepancy between knowledge and food hygiene behaviors (e.g. Mullan et al., 2013).

Next, the finding in relation to importance of food to the household budget has not - to our knowledge - been reported in previous studies. This finding may indicate that food safety precautions become increasingly necessary or immediate as food becomes relatively more valuable. Increasing employment opportunities in unorganised sectors within Hyderabad city – such as construction, taxi-driving, hospitality, etc. – attract large numbers of educated migrants from different parts of India. In this group of households, both husband and wife tend to work and earn moderate incomes and the share of food in their total expenditure is higher. As this group of households is likely to be more sensitive to food availability and food price instability, future research would do well to address the underlying reasons for the more protective practices among these households. Notably, the findings also indicate that belonging to the higher castes, having higher income or being younger or older, significantly increases the probability of belonging to the latent class labelled as *Less Consistent and More Exposed* to food safety risks among the households without a refrigerator. In contrast, belonging to the age group 30–36 or being obese made it more likely to belong to the larger *More Handling but Less Hygiene Oriented* latent class.

The findings in this study illustrate the relevance of using the latent class technique to look beyond methods of cluster analysis. The latent class technique draws on similarities among background features of individuals to examine if groups of individuals with similar background variables also reveal similarities in food safety behaviors. Therefore, identification through latent trait-specific behaviors has the potential to inform and direct behavior change interventions.

The analysis presented above shed light on the food safety behaviors exhibited by different household-groups. On the basis of the current findings, it would therefore appear that there is a need to address between-group differences in traits as well as coherencies in behaviors within the latent groups. The consistency issue warrants special attention and calls for creating awareness and positive attitudes towards food safety at home. There is also a specific need to tailor specific advice/education depending on whether households are using a refrigerator or not.

CRediT authorship contribution statement

Carl Johan Lagerkvist: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition. **Assem Abu Hatab:** Conceptualization, Writing - review & editing, Funding acquisition. **Swamikannu Nedumaran:** Conceptualization, Investigation, Data curation, Writing - review & editing, Funding acquisition. **Padmaja Ravula:** Conceptualization, Investigation, Data curation, Writing - review & editing, Funding acquisition.

Declaration of competing interest

The authors have no competing interests to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodcont.2020.107677.

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