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Kitchen cloths: Consumer practices, drying properties and bacterial growth and survival

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ABSTRACT

Kitchen cloths have an important role in maintaining kitchen surfaces hygienically clean but may also act as vehicles for cross contamination of pathogens from food spills to hands and other foods. The aim of the present study was to map consumer practices across Europe and identify main factors that may contribute to unsafe use of kitchen cloths, such as type of cloth and storage practices. Consumer practices related to cloths were investigated in a web-based survey (N = 2394), while drying properties and growth and survival of *Salmonella*, *Campylobacter* and non-pathogenic food associated bacteria in inoculated cloths were studied in laboratory tests mimicking consumer practices. Among consumers in six European countries, cotton and microfiber cloths were reported to be the most used cloth types for cleaning food preparation areas and wiping up spills. . Fifty-seven percent of the consumers reportedly hang the cloth to dry after use. A large majority (72%) changed their cloths at regular times, with an average reported frequency of every 6 days.

Large variations in water absorption (63–201 g) and drying rate (31.8–99.8% water loss after 4.5 h*)* among 17 types of commercially available cloths were found. Hanged up cloths dried faster than cloths stored crumpled as balls. *Salmonella* multiplied in all types of new cloths that were not hung to dry (crumpled), but about 3 log reduction or more were found after hanging cloths to dry for 24 h. For cloths collected from consumers, growth of inoculated *Salmonella* was not observed, but hanging the cloths resulted in more than 3 log reduction in numbers. A large variation in survival of *Campylobacter* was found depending on the type of cloth, but more than 5 log reduction was found after 24 h in all hanging cloths. A polypropylene and a viscose cloth with low water uptake and fast drying appeared to be the safest choice with a rapid reduction of both pathogens when hung (respectively 2 log and >6 log reduction for *Salmonella* and *Campylobacter* after 4.5 h) and reduction of *Campylobacter* when stored crumpled. The least safe cloth regarding pathogen growth and survival was a knitted cotton cloth with high water uptake and slow drying. There was no systematic difference in growth and survival of bacteria between microfiber cloths and cloths of other materials, nor between cloths with and without antimicrobial compounds.

The present study shows that 16% of consumers have practices that would allow pathogens to contaminate, grow and survive in cloths until the next use. Touching and using these cloths can lead to contamination of hands and food contact surfaces, and potentially to ingestion of pathogens. Consumers should be advised to change cloths after using them for meat spills, but also to choose cloths that dry fast and keep them hanging to dry between use.

1. Introduction

A high proportion of foodborne infections are acquired at home. In the period 2015–2020, 2537 outbreaks occurring in the domestic environment were reported in EU, where 43.8% caused by *Salmonella* and 5.4% by *Campylobacter* (European Food Safety Authority, 2022). The home environment is a reservoir for potentially large numbers of microbes (Enriquez, Enriques-Gordillo, Kennedy, & Gerba, 1997; Scott, 1999). Kitchen cleaning cloths (often also called kitchen dishcloths, generally referred to as “cloths” in the remaining of the paper) are

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commonly used by consumers to clean equipment and surfaces, however if not used properly they may also have the potential to spread bacteria including pathogens (Okpala & Ifeoma, 2019; Taché & Carpentier, 2014). For example, *Salmonella* and *Campylobacter* have been found in cloths after preparation of raw poultry (Cogan, Bloomfield, & Humphrey, 1999; Cogan, Slader, Bloomfield, & Humphrey, 2002; Enriquez et al., 1997; Gorman, Bloomfield, & Adley, 2002; Mattick et al., 2003). In a study in Mexico where 360 cloths were tested (cloths collected each week for 6 weeks from 60 households), >95% of the cloths were positive for *Salmonella* (Chaidez, Soto-Beltran, Gerba, & Tamimi, 2014).

Humidity in cloths may act as a double-edged sword. Humidity is needed for cloths to have a high cleaning effect (Moore & Griffith, 2006; Røssvoll et al., 2015) and the ability to absorb fluids is important when wiping up spills. On the other hand, a humid cloth is a niche for growth of microorganisms, including the pathogen *Salmonella* (Cogan et al., 2002), while bacteria may die in dry cloths (Scott & Bloomfield, 1990b). In a study where consumers wiped chopping boards that had been used to prepare chicken naturally contaminated with *Salmonella*, 90% of the cloths became contaminated with *Salmonella*. Of nine *Salmonella* positive cloths stored for 24 h folded in a Petri dish at room temperature, there was a 1 log increase in *Salmonella* count in three cloths and a 1–2 reduction in three of the cloths (Cogan et al., 2002).

Thus, for a cloth to have both a proper cleaning effect and be safe to use, a compromise regarding the ability to retain humidity may be needed. There are many different types of cloths available in the market, such as different types of cotton and microfiber cloths with different water absorption and drying rates, but it is not clear which types are best regarding microbial safety. Often other properties such as price and design are highlighted in marketing of cloths. There are also some cloths on the market containing antimicrobial products, but to our knowledge scientific evaluations of their antimicrobial effects in practical use are lacking.

When evaluating cloths related to food safety, it is also important to consider how consumers use and handle cloths. Research on food safety is often focused only on the microbial and epidemiological aspects of foodborne diseases; there is a need to complement this research with the investigation of social and behavioural data illustrating consumer practices in the domestic environment (Cardoso, Ferreira, Truninger, Maia, & Teixeira, 2021; Menini et al., 2022; Møretrø, Nguyen-The, et al., 2021). A recent ethnographic study conducted in Italy reports that improper use of towels, dishcloths and sponges promoting cross-contaminations was observed in 11 out of 14 families (Menini et al., 2022). Information on cloth-related practices is lacking in that regard, especially as there can be large variations in use of different cleaning utensils between different countries (Møretrø, Moen, et al., 2021).

In the present study, we aimed to map usage and storage of cloths among European consumers, and to evaluate how these practices affected survival and elimination of foodborne pathogens, thus affecting the risk of foodborne illness. We investigated consumers' self-reported usage of cloths in a web-based survey. In laboratory studies mimicking the reported practices, different types of cloths were examined for water uptake, drying rate, growth and survival of *Salmonella* and *Campylobacter* as well as other food related bacteria. The effect of drying on survival of *Salmonella* was also tested in used cloths collected from consumers. The consumer practices are discussed against the laboratory tests. Finally, safety advice is drawn to prevent pathogen contaminations from cloth usage in European households.

2. Materials and methods

2.1. Web-based survey among European consumers

A web-based cross-national survey on hygiene and food handling practices for diverse food categories was conducted among European households from 10 countries selected for representing geographical and cultural differences in Europe (Møretrø, Moen, et al., 2021). Consumer recruitment was administered by an international survey provider (Dynata). The survey was carried out in accordance with requirements from the Declaration of Helsinki and the European general data protection regulation (GDPR). Private households were selected by stratified random sampling based on the Nomenclature of Territorial Units for Statistics level 2 (NUTS2) and education level of the target respondent. The present work is originated in a total of N = 5735 consumers in six countries: Denmark, Greece, Hungary, Norway, Romania and United Kingdom. The remaining four countries from the original data set were excluded from the present work due to ambiguous translations of the word "cloth" in the survey questions. Across the six countries, 95.7% consumers declared being a cloth user, and 40% declared using a cloth for cleaning food preparation surfaces (Table 1) while 31% used a sponge and the remaining used kitchen roll or single-use wipes (not shown). The paper considers the specific subset of N = 2394 consumers who declared generally using a cloth for cleaning the countertop and other food preparation surfaces, and reports on a sub-selection of questions related to cloth types, usage, cleaning and storage practices. Based on microbiology results (see below), we consider the combination of specific habits that may put consumers at risk of illness and report the percentage of people following these risky practices in each population sample.

Table 1 testifies of an unbalanced number of respondents across countries linked to the sub-selection that used the cloth for food surface preparation cleaning. About 20% of the original survey respondents from Greece and Hungary reported to clean surfaces used for food preparation with cloths while around 60% did the same in Denmark and in Norway. Our selected sample for the study included 55% of females and had a mean age of 46 years, with slightly younger consumers in Greece and Romania than in United Kingdom and Denmark (Table 1). Overall, 53% of the respondents pursued some university education or equivalent and 56% were professionally active. Household income was perceived on average as "Just about the amount needed to make ends meet" except in Greece ("Somewhat below the amount needed to make ends meet"), with a variation around the average representing different social status. Fourty-eight percent of households were composed of at least one person at risk of severe foodborne illness, i.e. a pregnant woman, children under six years old, persons above 65 years old, or persons suffering of diabetes or immuno-deficiency, with a predominance in Hungary (63%) and Romania (55%).

2.2. Cloths used in laboratory tests

An overview of the 17 cloths used in laboratory tests is shown in Table 2. All cloths were washed once in a washing machine at 60 °C with detergent before use. Except for cloth no. 5, 15 and 17, which were bought online, nearly all cloths were purchased from local stores (supermarkets or houseware shops) in Norway. Cloths no. 18 and 19 were purchased in local stores in Portugal (antimicrobial cloths were not sold by Norwegian retail shops). Photos of all types of cloths are shown in Supplementary Fig. S1.

2.3. Water absorption and drying of cloths

Initially, 17 different cloths (see Table 2) were tested for their ability to absorb water after being submerged in water (21 °C) for 1 min. Excess water was allowed to drain off for 30 s, before weighing the cloths to determine the amount of water absorbed. The cloths were hung unfolded with clothespins on a drying line and weighted after 4.5 h and 24 h at 20 ± 1 °C, to determine the drying rate. The storage times were chosen to model situations where cloths were stored after use until the next meal (4.5 h) and when cloths were stored until the next day (24 h) before use. In addition, for six selected cloths (different materials, different drying rates in initial experiment, with and without antimicrobial compounds) the effect on drying of storing cloths hanging

Table 1
Socio-demographic characteristics of the survey participants.

	Denmark (N = 634)	Greece (N = 181)	Hungary (N = 226)	Norway (N = 586)	Romania (N = 397)	United K. (N = 370)	Total sample (N = 2394)
Participants selection	1033	880	1011	1006	985	1080	5995
Total original participants Share of original participants using a cloth for cleaning food preparation surfaces (%)[a]	61	21	22	58	40	34	40
Share of females (%)	56	48	58	57	53	54	55
Age (years), Mean (SD)	47.9 (17.2)	41.0 (14.4)	46.0 (17.4)	45.9 (17.2)	44.4 (15.8)	48.1 (16.8)	46.1 (16.9)
Education (%)							
Primary education	9	1	3	11	1	0	6
Secondary education	44	3	37	25	12	39	29
Vocational education	8	13	19	12	0	16	10
Higher education	36	83	40	48	87	44	53
Prefers not to answer	3	0	1	4	0	1	2
Occupation (%)							
Full-time job	40	56	53	36	63	40	45
Part-time job	10	10	8	14	4	18	11
Unemployed	6	9	2	4	2	6	5
Education	12	8	8	11	7	4	9
Retired	25	14	20	19	20	22	21
Other	8	3	8	16	4	10	9
Perceived household income, mean (SD)[b]	3.3 (1.0)	1.9 (1.1)	2.9 (1.2)	3.3 (1.2)	3.1 (1.1)	3.3 (1.0)	3.1 (1.2)
Household size, mean (SD)	2.2 (1.2)	2.9 (1.3)	2.9 (1.4)	2.3 (1.2)	2.9 (1.2)	2.5 (1.4)	2.6 (1.3)
Households with members in risk groups (%)							
Pregnancy	3	7	6	5	6	6	5
Children <6 y.o.	8	13	13	8	14	8	10
Persons >65 y.o.	24	19	35	23	30	30	26
Diabetes or immuno-deficiency	17	19	31	18	24	14	19
At least one of the risk groups[c]	43	43	63	44	55	50	48

[a] "In general, how do you clean surfaces used for food preparation?", with cleaning tool alternatives: With a cloth/With a sponge/With kitchen roll/With single-use wipes/None of the above.

[b] "Considering the minimum amount of money your household needs to make ends meet, would you say your total household income after tax is …", with answers collected on a 5-point scale, 1: Far below that amount; 2: Somewhat below that amount; 3: Just about the same as that amount; 4: Somewhat above that amount; 5: Far above that amount (n = 2169 answers; DK = 563, EL = 156, HU = 213, NO = 527, RO = 370, UK = 340).

[c] Extracted from answers on the four risk groups.

unfolded, hanging folded double and laying crumpled as a ball for 4.5 h and 24 h was studied, by weighing the cloths after storage.

2.4. Growth and survival of bacteria on new cloths

Six types of cloths (selected based on different drying rates in experiments described above and presence/absence of antimicrobial compounds), were inoculated with a suspension of a mixture of two *Salmonella* strains (*S.* Infantis, *S.* Enteritidis), two *Campylobacter jejuni* and five bacteria (*Kocuria* sp., *Moraxella osloensis*, *Pseudomonas* sp., *Staphylococcus* sp., *Serratia liquefaciens*) isolated from kitchens and food soils based on poultry meat, egg and vegetables as described previously (Møretrø, Moen, et al., 2021). The bacteria were grown overnight in tryptic soy broth, (TSB, Oxoid) at 30 °C with 150 rpm agitation, and mixed and added to a food soil mixture (prepared as described previously (Møretrø, Moen, et al., 2021)) in a concentration of about 10^8 per ml for kitchen bacteria and *Campylobacter* and 10^6 per ml for *Salmonella*. At day 0, the cloths were inoculated and soiled by immerging them in the bacteria-soil suspension. The volume of the bacteria-soil suspension was determined in prior tests to find the maximum water volume each type of cloth could absorb. The cloths were either hanged folded double on drying lines or laid crumpled as a ball. After 24 h and 48 h, water was added. The humidity in the room was in the range 30–43% RH and the temperature 19.5–21.5 °C during the experiment. The cloths were analyzed immediately after inoculation (t = 0) and after 4.5 h, 24 h and 72 h. Each cloth was transferred to a bag, added 50–100 ml buffered peptone water and treated with a Stomacher for 60 s, and the number of bacteria determined by plating and cultivation on PCA (total viable count), XLD (*Salmonella*) and mCCDA (*Campylobacter*). The experiment was performed with two (time 0, 24, 72 h) or three (time 4.5 h) technical replicates.

2.5. Growth and survival of bacteria in used cloths

Convenience samples of 11 used cloths were collected from Norwegian consumers (colleagues, students at our institute or their family members). The cloths were added *Salmonella*, by immersing them in 5–50 ml dH_2O added 1 ml of a mixed suspension of the two *Salmonella* strains (described in section 2.4) (overnight cultures grown in TSB, diluted in sterile dH_2O to approximately 6 log cfu/ml). Some of the cloths were humid when collected from consumers. The maximal water uptake capacity of the cloth was estimated based on a visual comparison between the used cloth and new cloths upon which we had done prior water uptake studies with. Then the volume dH_2O to add was decided after subtracting the weight of the cloth from the estimated maximal uptake capacity. To test the effect of drying vs humid conditions, the cloths were cut in two parts, one cloth part was hanged up on a drying line and the other stored in a closed plastic bag, for 20 h at 20 ± 1 °C, before analyses. The relative humidity in the room was 41–48 %RH. The cloths were sampled by transferring them to a bag and adding 50 ml buffered peptone water (BPW), before Stomacher treatment for 60 s before enumeration of bacteria. In parallel with the used items, as four new cloths (no. 9, chosen as a type of cloth that dried rapidly) were used as controls. The controls were added *Salmonella* (40 ml dH_2O and 1 ml *Salmonella*-mix), then two of them were hanged up and two were placed in bag, as for the used items. After about 20 h at 20 ± 1 °C, the concentration of bacteria was determined as described above. To present the bacterial concentration per cloth, bacterial counts were multiplicated by two, since the cloths were cut in two parts.

2.6. Calculations and statistics

Consumer data was summarized in descriptive tables for the total sample as well as per country. Multiple choice questions were summarized as percentages and numerical answers as means and standard

Table 2
Overview of cloths tested.

No.	Product	Material[a]	Weight as dry (g)	Antimicrobial agent
2	Microfiber cloth	88% polyester, 12% polyamide	32.5	No
4[b]	**Knitted cloth**	**100% cotton**	**50.7**	**No**
5	**Microfiber cloth**	**80% polyester, 20% polyamide**	**35.8**	**No**
6	Knitted cloth	100% cotton	37.4	No
8	Cloth	Viscose	10.2	No
9	**Cloth**	**85% viscose, 15% polypropylene**	**15.2**	**No**
10	Microfiber cloth	80% polyester, 20% polyamide	31.0	No
11	Cloth	100% regenerated cellulose	7.5	No
15	**Microfiber cloth**	**70% polyester, 30% polyamide**	**19.1**	**Silver**[c]
17	**Microfiber cloth**	**70% polyester, 30% polyamide**	**33.0**	**Silver zirconium phosphate**
18[d]	**Microfiber cloth**	**50% viscose, 30% polyester, 20% polypropylene**	**20.1**	**Silver chloride**
19[d]	Cloth	82% viscose, 18% polypropylene	14.9	Zinc pyrithione
23	Microfiber cloth	88% polyester, 12% polyamide	34.2	No
24	Cloth	100% cotton	35.6	No
25	Cloth	70% cellulose, 30% cotton	8.8	No
26	Cloth	100% cotton	39.9	No
27	Cloth	85% viscose, 15% polyester	18.8	No

[a] Information from product labels.
[b] Types of cloths included in the microbial experiments (section 2.4) are shown in bold.
[c] Claims made on product labels linked to antibacterial content: "Strong antibacterial effect, and bacteria that come into contact with a humid cloth die within 12 h" (no. 15), "reduces bad odour caused by moulds" (no. 17), "stops/prevents bad odour" (no. 18 and 19).
[d] All cloths were bought in Norway, except for no. 18 and 19, which were from Portugal.

deviations. For some answer alternatives of specific relevance to cloths, countries were compared with statistical testing: Pearson's Chi-squared tests were used, followed by pair-wise comparisons via Pearson's Chi-squared tests with a Bonferroni correction for categorical answers and ANOVAs, followed by Tukey tests with a Bonferroni correction for numerical answers.

Bacterial numbers were log transformed and mean values and standard error of the mean calculated. One-way ANOVA was used to calculate statistical differences between log transformed microbial numbers of cloths hanged to dry or stored folded. Analysis was done both including and excluding data below the detection limit and the same level of significance were found. Also, One-way ANOVA was used to test differences between cloths with regard to drying rates with the percentage of remaining water after 4.5 h (calculated from the mean water contents of two experiments for each cloth type) used as response variable. To be able to run the statistical analysis, the cloths were divided into four categories depending on the type of fabric: 1) Polyester and Polyamide (6 cloths) 2) Cotton (4 cloths) 3) Viscose (1 cloth only viscose, three cloths of viscose and polyamide and one cloth of viscose and polyester and 4) Cellulose (one cloth only cellulose and the other of cellulose and cotton).

Risky cloth usage practice was defined as a binary variable based on the identified critical factors for bacterial growth in the subsample of participants that used a cloth for cleaning food preparation surfaces and ate chicken at least once a month. Countries were compared with a Pearson's Chi-squared test, followed by pair-wise comparisons via Pearson's Chi-squared tests with a Bonferroni correction. Additionally, a multivariate logistic regression was used to compare risky practices between countries including further socio-demographic variables.

Consumer data was analyzed in R, version 4.0.4 (The R Foundation), microbiology data in MinitabMinitab (Minitab 18.1, 2017, www.minitab.com). Statistical significance was determined based on an alpha level of 5%.

3. Results

3.1. Consumers' self-reported use of cloths

The web-survey consulted 2394 consumers, all users of cloths for cleaning food preparation surfaces about the choice, use, storage and hygiene of cloths. Similar numbers reported to use microfiber (52%) and cotton (46%) cloths, 26% used synthetic cloths and 12% reported to use antimicrobial cloths. Differences between countries occurred, with cotton being most common in Hungary (64%) and microfiber cloths most common in Norway (66%) and Greece (55%). One out of four used antimicrobial cloths in Greece and Romania, and less than one out of 20 in Denmark (Table 3).

In addition to the general cleaning of the countertop, cloths were also used for doing the dishes (11%). This was especially reported in Romania (29%) and the United Kingdom (22%). However, the use of dish-washing machines (48%), sponges (34%) or brushes (23%) were generally more common. Moreover, cloths were used for wiping up chicken juices from the countertop (44%) or the chopping board (7%). Regarding country differences, the practice of wiping up spilt juices from raw chicken on the countertop with a cloth ranged from 28% in Greece and 30% in Hungary, to 56% in Denmark and 55% in Romania. Using a cloth to clean the chopping board after using it for chicken was most common in Romania (15%), possibly linked to the higher usage of cloths for doing the dishes in this country (29%). Further, the consumers were asked how they kept cloths after use. On average, 57% reported hanging the cloth, while 26% left it beside the sink, 4% in the sink and 7% at the counter. Norwegian consumers were the most likely to be hanging the cloth to dry (78%), while Romanian and British consumers were the least likely to do so and equally left it hanging or beside the sink (just above 40%).

Changing the cloths on a regular schedule (72%) was more common than changing cloths based on factors that could indicate possible contamination level, either by sensory cues (looks dirty, 45%; smell, slime, 29%; clean up dirt (soil), 27%) or by risky use (meat/fish juices or egg, 30%). The probability of changing the cloth after wiping up meat/fish juices or egg spills was highest in Denmark and Norway, with 41% and 33% of the respondents, respectively. In the other countries, one in four consumers reported the same. Most (on average 64%, varying from 34% in Denmark to 92% in Greece) reported to use the cloth or sponge for more than three days before changing it, with a global mean at 6 days (Table 3).

3.2. Water uptake and drying rate

As shown in Fig. 1, there was a large variation in water uptake and drying rate among the different cloths tested. All cloths were dry (containing less than 1.5% water) after hanging for 24 h. Only two cloths (number 8 and 15), one made of microfiber and the other of viscose and both with a relatively low initial weight and low water uptake, were dry after 4.5 h. Apparently, considering all cloths it was not a clear relation between drying time and the weight of the cloth, water uptake nor the cloth material (Fig. 1). Some cloths (e.g. no. 4, 10, 17) had high water uptake and dried slowly, some cloths had high water uptake but dried more rapidly (e.g. cloth no. 9, 18), while others had low water uptake and dried rapidly (e.g. no. 5, 8, 15). When the cloths were grouped in the four categories polyester/polyamide, cotton, viscose, and cellulose, there was no statistically significant difference in drying rate between

Table 3
Cloth practices reported in answer frequencies (%).

	Total sample (N = 2394)	Denmark (N = 634)	Greece (N = 181)	Hungary (N = 226)	Norway (N = 586)	Romania (N = 397)	United K. (N = 370)	Country comparison [e] (p-value)
Material: In general, what types of kitchen cloths do you use?								
Cotton	46	46 b	40 b	64 a	42 b	49 b	44 b	X^2 (5, N = 2394) = 36.2, p < .001
Microfibre	52	48 bc	55 ab	39 cd	66 a	55 b	37 d	X^2 (5, N = 2394) = 103.1, p < .001
Synthetic	26	31	36	12	20	30	23	
Antimicrobial	12	3	25	14	7	24	14	
Other	5	7	4	4	5	2	6	
Use: Typically, how do you wash up or clean dirty dishes? [cleaning tools only] [a]								
Dishwasher	48	61	34	28	79	11	35	
Cloth	11	3 c	6 bc	10 b	3 c	29 a	22 a	X^2 (5, N = 2394) = 263.0, p < .001
Sponge	34	17	71	60	8	68	35	
Brush	23	35	9	19	26	10	19	
Kitchen roll	4	2	5	7	3	8	5	
Other	2	3	1	1	3	1	2	
Storage: In general, how do you typically keep a kitchen cloth after use? [b]								
Hanging	57	57 b	54 bc	62 b	78 a	42 c	41 c	X^2 (5, N = 2394) = 181.2, p < .001
Left in sink	4	2 b	2 ab	3 ab	5 ab	3 ab	6 a	X^2 (5, N = 2394) = 17.1, p = .004
Left beside the sink	26	30 b	30 ab	15 c	6 d	43 a	37 ab	X^2 (5, N = 2394) = 228.3, p < .001
Left on counter	7	3 b	12 a	9 a	7 ab	9 a	6 ab	X^2 (5, N = 2394) = 25.5, p < .001
I always dispose of or change the cloth after use	5	5	2	9	4	2	8	
Other	2	3	1	2	1	2	2	
Change: In general, when do you decide to change to a new/clean kitchen cloth or sponge used to wash kitchen countertops and other surfaces?								
When they look dirty	45	37	53	42	47	54	43	
When they are smelly or slimy	29	18	46	17	32	40	28	
When they were used to clean up dirt (soil)	27	28	33	19	25	36	23	
When they are used to wipe up meat/fish juices or egg	30	41 a	25 bc	24 bc	33 ab	24 c	23 c	X^2 (5, N = 2394) = 59.5, p < .001
I do this at regular times	72	74	70	69	74	71	65	
Other	5	12	1	4	3	1	5	
Duration: In general, how long do you typically use the same kitchen cloth or sponge for before using a fresh one? [b]								
Up to 2 days	36	66	8	22	39	12	29	
3 days or more	64	34	92	78	61	88	71	
Mean duration (SD), in days	6 (4)	3 (3) a	10 (4) e	7 (4) c	5 (4) b	8 (4) d	6 (5) c	F(5, 2388) = 49.4, p < .001
Number of respondents for chicken-related questions [c]	2001	498	154	205	488	347	309	
Share of original participants using a cloth for cleaning food preparation surfaces and were respondents for chicken-related questions (%) [c]	33	57	15	20	47	35	29	
Use: If juices from chicken are spilt on e.g. the counter top, how would you wipe this up [cleaning tools only] [a]								
With a cloth	44	56 a	28 d	30 d	35 cd	55 ab	44 bc	X^2 (5, N = 2001) = 95.7, p < .001
With a sponge	17	4	40	33	3	39	10	
With kitchen roll	37	41	34	33	45	31	31	
With single-use wipes	11	5	5	22	8	17	12	
Other	1	2	0	1	1	0	1	
Use: How would you clean the chopping board after using it for chicken and before reusing it? [cleaning tools only] [a]								
Cloth	7	3 c	6 abc	6 abc	5 bc	15 a	8 ab	X^2 (5, N = 2001) = 52.1, p < .001
Sponge	20	11	41	32	7	38	14	
Brush	21	32	14	20	29	8	10	
Kitchen roll	6	3	8	10	5	7	5	
I always use separate chopping boards	19	24	15	19	22	9	20	

(continued on next page)

Table 3 (*continued*)

	Total sample (N = 2394)	Denmark (N = 634)	Greece (N = 181)	Hungary (N = 226)	Norway (N = 586)	Romania (N = 397)	United K. (N = 370)	Country comparison [e] (p-value)
Other	4	5	1	0	6	1	3	
Risky practice								
Cleans chicken juices on countertop OR on chopping board with a cloth, AND does not change it after cleaning meat/fish juices or egg AND does not hang up the cloth[d]	16	14 bc	12 bcd	10 cd	7 d	29 a	22 ab	X^2 (5, N = 2001) = 94.7, p < .001
Share of risky practice out of the original survey sample of N = 5735 respondents	5	7	2	2	3	11	7	

[a] The original survey offered additional options related to other domains (water usage, detergents, rinsing and drying techniques) that are not reported here.
[b] Multiple-choice question with single answer.
[c] Respondents who answered "Never or less than once a month" to the question "How often do you or other members of your household eat dishes at home that you prepare from raw chicken?" did not receive chicken-related questions.
[d] Extracted from the combination of four questions.
[e] Pearson's Chi-squared tests for categorical answers and ANOVAs for numerical answer categories of particular interest. Confidence levels are displayed in compact letter display superimposed over country values. Different letters (a, b, c, …) indicate significant differences.

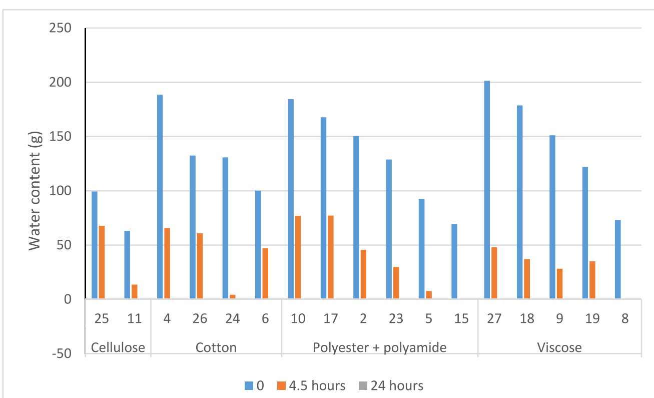

Fig. 1. Maximum water absorption (time 0) and water content of cloths hanging to dry for 4.5 and 24 h. A value of zero indicates a dry cloth. Numbers on x-axis are referring to cloth product no., see Table 2.

these categories (Fig. 1). However, separating between different materials, it was a tendency that cloths absorbing more water also contained more water after 4.5 h.

Six cloths were selected for further study, including cloths with fast and slow drying and with and without antimicrobial compounds. When cloths were stored as crumpled as balls or hanging unfolded or folded double, all hanging cloths were dry after 24 h (Fig. 2B). After 4.5 h there was a tendency that cloths hanging double dried faster than cloths hanging folded double (Fig. 2A). In both the experiments shown in Figs. 1 and 2, the cloths no. 5, 9 and 15 dried rapidly.

3.3. Effect of storing conditions on drying rate and bacterial growth and survival in new cloths

To simulate absorption and survival of pathogens and other bacteria in cloths during storage in kitchens, cloths were added *Salmonella*, *Campylobacter* and a cocktail of bacteria found in food and kitchen environments in a suspension with a mixed food slurry. Overall, there was a clear tendency of higher bacterial numbers (TVC, *Salmonella* and *Campylobacter*) in cloths laying crumpled compared to cloths hanging to dry (Fig. 3). For all cloths laying crumpled, there was growth until 24 h up to levels of 10–11 and 8.5 log cfu per cloth, for TVC and *Salmonella*, respectively. The numbers leveled off and were stable until 72 h. For *Campylobacter* the counts decreased over time, with some differences between types of cloths. For cloth no. 9 and no. 17 the *Campylobacter* numbers dropped to low levels (<3 log per cloth) after 72 h in cloths stored crumpled, while the levels were >6 log for the other cloths.

For cloths hanging to dry, there was growth of *Salmonella* and TVC (0.5–1.5 log) the first 4.5 h followed by reduction over time. In hanging cloths, the bacteria (TVC, *Salmonella* and *Campylobacter*) died faster in cloths no. 9 (made of viscose and polypropylene, high water uptake) and 15 (Microfiber cloth with silver, low water uptake) than in the other cloths. As previously shown in Fig. 1, weighing of the cloths showed that cloths no. 9 and 15 dried rapidly (Supplementary Table S1).

Three (no. 15, 17, 18) of the six cloths tested contained antimicrobial products (Table 1), however there was no apparent systematic difference in growth or survival of bacteria between cloths with or without antimicrobial compounds.

In total, three experiments were performed where bacteria were added to six types of new cloths in laboratory studies, but the results could not be presented in one figure because of variations in design of the experiment. However, the two other biological replicated confirmed that: 1. An increase in TVC in all cloths laying crumpled and less or no increase in hanging cloths. 2. Higher numbers *Salmonella* in cloths laying crumpled than in hanging cloths. 3. A die-off of *Campylobacter* over time in all types of cloths (Supplementary Figs. S3 and S4).

3.4. Effect of storing conditions on bacterial growth and survival in cloths retrieved from consumers

Eleven used cloths were collected from consumers. Based on a visual comparison with new cloths of known composition, the eleven collected cloths were classified as 5 microfiber cloths, 4 knitted cotton cloths and three viscose cloths. The consumers providing cloths filled out a form with information about their cloth and their usage of the cloth. All eleven cloths were reported to be in daily use. The time since last changing cloth were reported to be between 2 days and 2 months (a majority of six had been used for one week). Eight reported to change their cloth due to visual/sensory cues (dirty, worn, odour), while three reported that they changed cloths when they considered it to have been used for a long time. Nine of the cloths were reported to be hanging between use, while two cloths were store folded/crumpled.

To investigate whether *Salmonella* could grow in consumer cloths with soil and bacteria from kitchen environments, eleven used cloths were collected from Norwegian consumers. The cloths were inoculated with *Salmonella* and stored for 24 h. To test the effect of storage conditions, each cloth was cut in two, with one half hanging to dry (H) and the other stored in a plastic bag (B) to keep it humid for 24 h. *Salmonella* and total bacterial counts were on average 2.5 log lower (p = .000, F = 74.3) and 1.2 log lower (p = .015, F = 7.2), respectively, in hanging used cloths compared to cloths in bags (Table 4, One-way ANOVA). *Salmonella* was reduced to below the detection limit (3 log) in five used cloths and in both of the control cloths (new, not used) that were hanging. There was growth of *Salmonella* in three of the cloths that were stored in

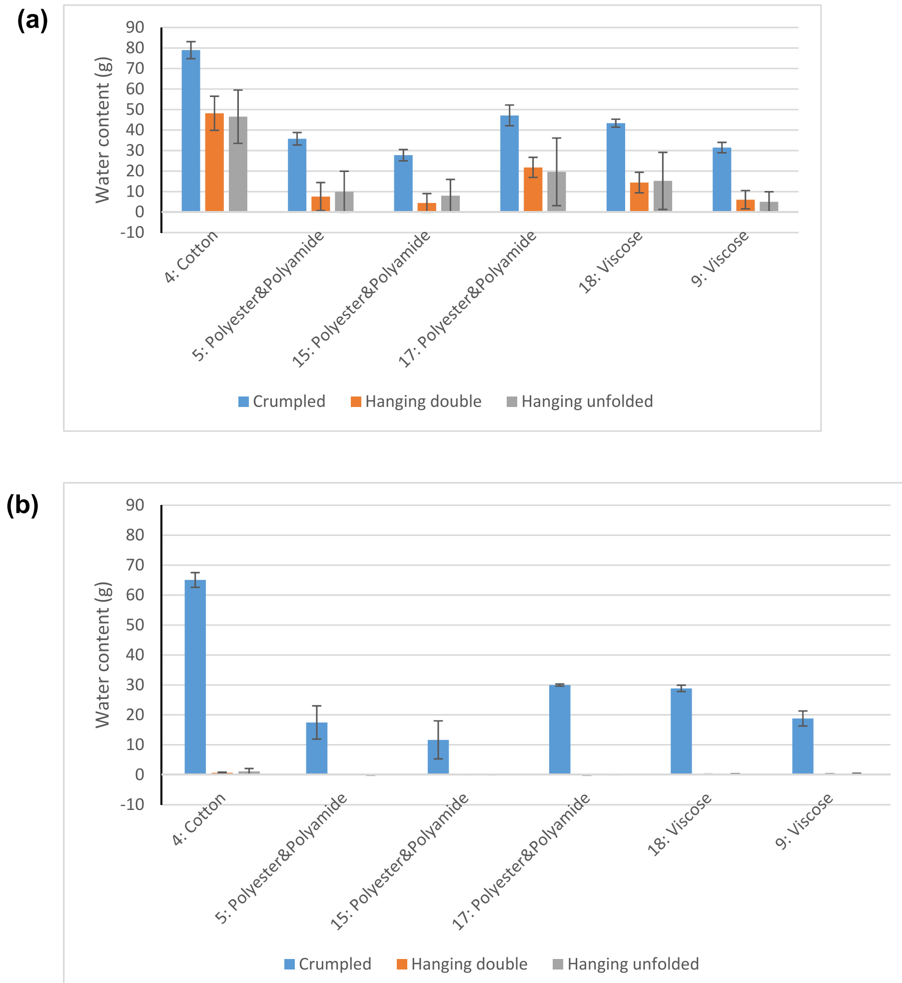

Fig. 2. Water content after storage of cloths stored crumpled as a ball or hanging unfolded or hanging double over a drying line for 4.5 h (A) or 24 h (B). A value of zero indicates a dry cloth. Initially, the cloths were added the maximum water volume they absorbed. Means and standard errors are shown. Numbers on x-axis are referring to cloth product no., see Table 2.

bags, a clear decrease in one cloth while the *Salmonella* level was relatively stable (<1 log variation compared to added *Salmonella*) in the remaining seven cloths. (Supplementary Fig. S5). For control cloths, the counts for *Salmonella* and total bacteria were on average 2.5 and 2.2 log lower, respectively, in hanging cloths compared to cloths in bags.

3.5. *Risky consumer practices*

Based on the findings from the microbiological studies, we considered that the combination of three specific habits may put consumers at particular risk of illness: wiping up meat juices (countertop or chopping board), not systematically changing the cloth after wiping up meat juices, and not hanging the cloth to dry. On average, 16% of consumers who use a cloth for cleaning food preparation surfaces and prepare dished from chicken at least once per month reported this combination of practices. Country comparison via Pearson Chi-square test showed significant differences in risky practices, varying from 7% in Norway to consequential numbers in the UK (22%) Romania (29%) and Denmark (14%) (Table 3). A multivariate logistic regression which included sociodemographic variables confirmed country differences and further indicated that respondents age was associated with a decreased odds ratio for risky cloth usage (Supplementary Table S2).

Regarding the general population (including non-cloth users as well as cloth users) risky practices corresponded to 5% of the consumers in the six countries, with the highest numbers in Romania (11%), Denmark (7%) and the UK (7%). The raw data for this publication has been deposited in a data repository: https://data.mendeley.com/drafts/5nbpnt3wdd.

4. Discussion

In the present study, consumers across six European countries reported their routine practices for cloths usage and storage. This section discusses the findings in light of our laboratory experiments investigating drying characteristics of cloths as well as bacterial growth and survival in cloths.

4.1. *Practices affecting contamination of cloths*

Salmonella and *Campylobacter* are not commonly found on European kitchen surfaces but can occasionally been found after handling contaminated foods (Møretrø, Nguyen-The, et al., 2021). Across the six countries, more than 40% of households reported to use a cloth to wipe off chicken juices from the countertop and 7% from a chopping board used for chicken. The variation between countries were high, from 28% in Greece to 55% in Romania and Denmark using cloths to wipe up spills. For many countries the explanation for a lesser use of cloths was the use of a sponge instead. According to The European One Health report, 38.9% of broiler carcasses are positive for *Campylobacter* and 18% of raw poultry products are positive for *Salmonella* (European Food Safety

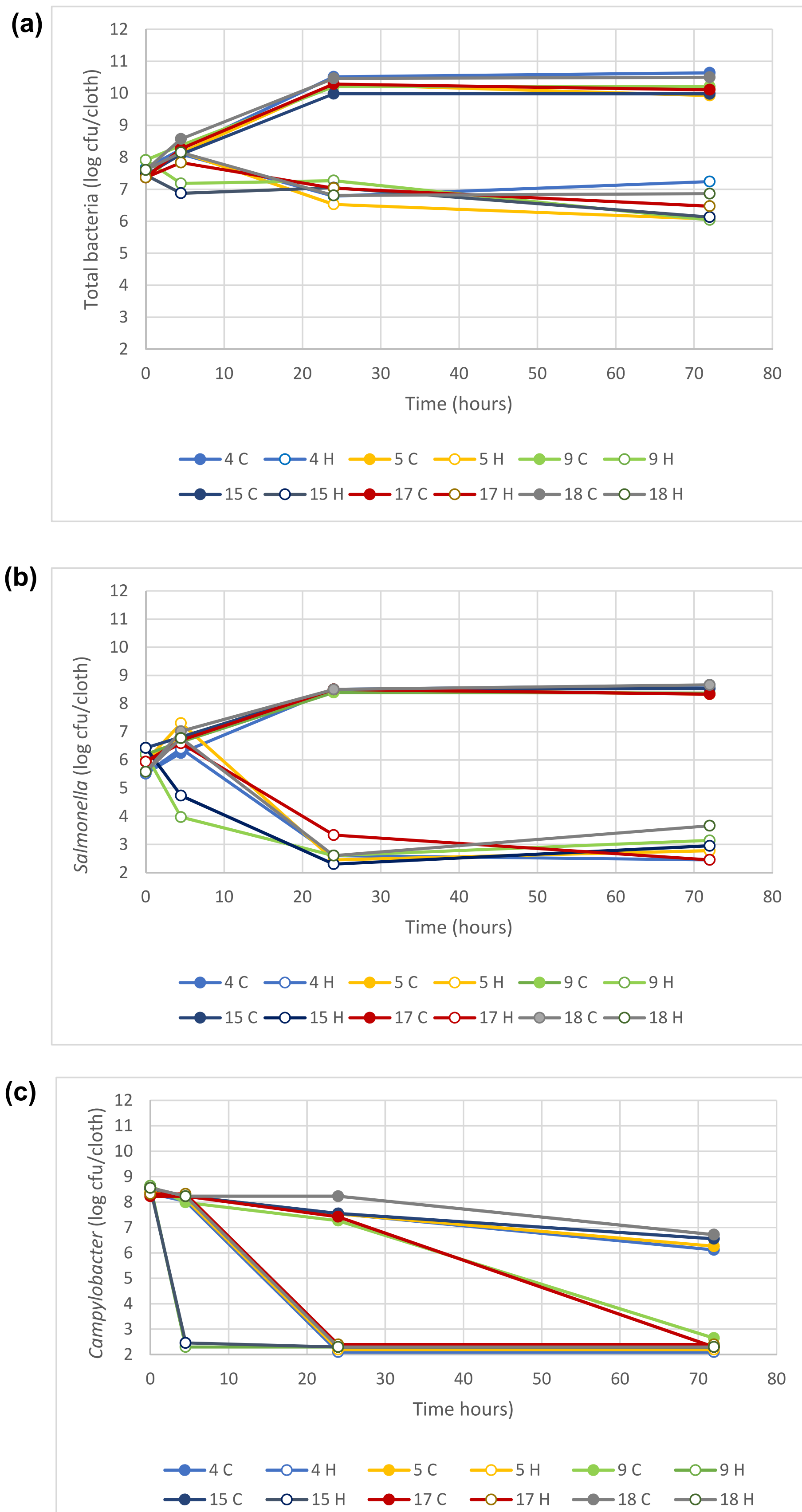

Fig. 3. Growth/survival of total bacteria (A), *Salmonella* (B), *Campylobacter* (C) in cloths. The cloths were either laying crumpled (C) or hanging over a drying line (H) for 4.5, 24 and 72 h. Numbers are referring to cloth product no., see Table 2. Cloths no. 15, 17 and 18 contained antimicrobial products. The detection limit was 2.3 log per cloth. Due to overlapping data points (below detection limit <2.3 log) for *Campylobacter*, all data points for cloth no. 4 H, 5 H and 17 H in Figure C have been subtracted 0.2, subtracted 0.1 and added 0.1 log, respectively, to improve the visibility of the results. Mean values are shown.

Table 4
Total bacteria and *Salmonella* in cloths added *Salmonella* and kept hanging (H) or stored humid in a plastic bag (B) for 20 h at room temperature (19 ± 1 °C). Cloths were added 6.0 log cfu *Salmonella* per cloth.

Cloth type	n	Storage	*Salmonella*	Total viable count
Used cloths	11	Hanging	3.3 (0.1)[a]	8.4 (0.4)
	11	Bag	6.7 (0.4)	9.6 (0.2)
New control cloths[b]	2	Hanging	<3[c]	3.4 (0.4)
	2	Bag	5.5 (0.1)	5.6 (0.2)

[a] Means in log per cloth with standard errors in parentheses. Four of the 11 hanging cloths were negative for *Salmonella* (<3 log/cloth).
[b] Control cloths were of type no. 9.
[c] Below detection limit, 3 log/cloth.

Authority & European Centre for Disease Prevention and Control, 2021). Contamination of cloths (or sponges) with pathogens from chicken is therefore not a rare event, and there are several reports of findings of *Salmonella* and *Campylobacter* in cloths after preparation of raw poultry (Cardoso et al., 2021; Cogan et al., 1999; Cogan et al., 2002; Enriquez et al., 1997; Gorman et al., 2002; Mattick et al., 2003). Reusing the cloth for further surface cleaning may therefore spread bacteria to new surfaces (Scott & Bloomfield, 1990b; Taché & Carpentier, 2014). In an ethnographic study of 18 households supported with microbiological analysis of sample swabs, Cardoso, et al. (2021) report that in line with observational data, one kitchen cloth was contaminated by *Campylobacter jejuni* following the direct contact of the cloth with raw poultry. It should be noted that *C. jejuni* has also been reported to be transmitted from chicken to other areas due to improper handling practices (i.e., wrongly using cloths, washing hands without soap, cleaning boards with knives) in commercial restaurant kitchens, despite their professional background (Lai et al., 2022). This illustrates how challenging avoiding cross-contaminations may be to laypersons. Also, other food types than chicken may contain *Campylobacter* or *Salmonella* (e.g., pork, eggs), but this was not investigated in the present study and chicken was utilized as a proxy for detecting the general habit of wiping up potentially risky food spills with a cloth. Indeed, one may reasonably assume that consumers who use a cloth for wiping up raw chicken juice, also use the cloth across any type of food spills.

To represent a risk, not only the occurrence, but also the numbers of pathogens are crucial. In a study where people prepared raw chicken naturally contaminated with *Campylobacter* or *Salmonella* on a cutting board, 40% of the cloths used to wipe the cutting board after preparation contained >1000 cfu of *Campylobacter*, while 5% of the cutting boards contained >1000 cfu of *Salmonella* (Cogan et al., 2002). These findings are in line with studies showing lower numbers of *Salmonella* on chicken than what reported for *Campylobacter* (European Food Safety Authority, 2010; Luber, 2009). Even if these studies show that high numbers of pathogens can be accumulated in cloths, and as discussed below there is a risk of a growth of *Salmonella* to even higher levels in humid cloths, it is still difficult to evaluate the risk of contaminated cloths for human health as studies on transfer rates from cloths to hands and/or mouth are lacking.

4.2. Storage practices affecting growth and survival of bacteria

On average, 57% of households reported to hang the cloth after use, while 30% left the cloth in or beside the sink after use. The latter was especially the case in Romania (43%) and in the UK (37%). Based on an intervention study in 371 households, Kirchner (2020) reports that sinks and their nearest vicinity (0–15 cm) had the highest frequency of contamination after cooking inoculated chicken thighs with *E. coli* DH5-α (a non-pathogenic strain that behaves similarly to pathogenic *E. coli*). Also *Campylobacter* has been detected in sinks after preparation of raw poultry (Møretrø, Nguyen-The, et al., 2021). Storing cloths in or beside the sink may therefore induce a direct risk of contamination of the cloth in the case of preparation of contaminated food.

Moreover, storing the cloth in or beside the sink does not allow proper drying. In the laboratory experiments a link between humidity and microbial survival and growth in cloths was found both for new cloths and for cloths that had been used by consumers. Hanging the cloth to dry, killed and/or inhibited growth of bacteria (including *Salmonella* and *Campylobacter*), while when the cloths were kept humid by storing them crumpled or in plastic bags, bacteria, including *Salmonella* grew, and *Campylobacter* survived longer. Reduction of *Salmonella* in dry cloths is in line with the results from a former study (Scott & Bloomfield, 1990b). An option to obtain less humid cloths, is to use a type of cloth that dries fast. The survey respondents reported using cloth in microfiber (52%), cotton (46%) and synthetic material (26%). In the laboratory study it was shown that in a viscose/polypropylene cloth (no.9) and a microfiber cloth (no.15) that dried fast, the bacteria, including *Salmonella* and *Campylobacter* died more rapidly than in other cloths. However, no systematic differences between materials in cloths were found. Consequently, the type of storage of the cloth (hanging vs laying crumpled) appeared to affect the drying rate of the cloth and growth/-survival of bacteria more than the material of the cloth.

For cloths not hung to dry, the new, unused ones showed quite consistent results across the six types tested, with growth of *Salmonella* the first 24 h before growth leveled off, probably due to nutrient limitation and competition with the added background microbiota. This was not the case for the used cloths collected from consumers, where growth (three cloths), no growth (seven cloths) and reduction (one cloth) in *Salmonella* numbers were observed. Possible explanations for the variation between cloths, are different nutrient levels or microbiota influencing *Salmonella* growth and survival. However, further investigation is recommended, as the microbial flora of the cloths was not investigated in the present study.

The total number of bacteria after storage at humid conditions were very high and similar for the artificially contaminated cloths and cloths collected from consumers, with around 10 log cfu/cloth. For dried cloths, the numbers were lower, with a mean of 8.4 log cfu for used cloths from consumers and 6–7 log cfu for artificially contaminated cloths. In a UK study, the mean bacterial numbers of cloths used for three days was about 6 log cfu (Scott & Bloomfield, 1990a). In a study of 569 dishcloths collected in China, the median bacterial level was about 6 log cfu/cm^2 of the cloth (the areas of the cloths were not given) (Shen et al., 2014). Previous research reported no significant difference between the microbial load of 54 cloths collected from British consumers regardless of their wet or dry condition, use duration and usage purpose (wiping surface or washing up) and where none of the samples featured *Salmonella* nor *Campylobacter* (Hilton & Austin, 2000).

Campylobacter in general does not grow *in vitro* and is sensitive to drying (Burgess et al., 2016), and the results from the present study supported this. Previously, we added *Salmonella* and *Campylobacter* to kitchen sponges and brushes in similar experiments as described for cloths in the present study. The survival of *Salmonella* and *Campylobacter* were comparable in cloths hanging to dry and brushes, while the growth/survival was higher in the humid cloths than in sponges (Møretrø, Moen, et al., 2021).

4.3. Reuse of cloths

As discussed above, cloths may become contaminated by pathogenic bacteria when used in kitchens, especially in high-risk situations like wiping up meat spills. Hanging the cloths to dry is likely to reduce the number of *Campylobacter* and inhibit growth of *Salmonella*, but survival of *Salmonella* may still occur. Less than one in three of the surveyed European consumers reported to replace their cloth or sponge after wiping up meat spills, so it is likely that many do not change cloths even when used in high-risk situations. Visible dirt or smell seemed to be equally or more important than exposure of the cloth to high-risk foods as a reason for changing the cloth/sponge, as reflected by the survey. The most common reason reported for changing the cloth/sponge was to replace it according to a regular schedule (72%), with an average usage length of 6 days ranging from three days in Denmark to 10 days in Greece. As *Salmonella* may survive in cloths, and visual or smell signals are not likely to detect pathogens, both these practices (changing at regular times or based on sensory cues) have higher risks than changing the cloth after it has been used in high-risk situations. Further, Menini et al. (2022), observed that even though dishcloths, towels and sponges may have distinct theoretical usage areas (such as cleaning surfaces, drying hands and washing dishes), their specific functions were not respected in practice, as they were used interchangeably for different purposes across family members. As an example, while the wife in a family was convinced that some dishcloths were used only for the hands; her husband was observed using them to dry the sink and parts of the kitchen countertop (Menini et al., 2022). Consequently, the importance of systematically replacing cloths after wiping up high-risk spills should be especially highlighted in non-single households.

4.4. Effect of antimicrobial cloths

Fourteen percent of the survey respondents reported using antimicrobial cloths, with the highest popularity in Greece (25%) and Romania (22%). As the same cloths with and without antimicrobial agents were not available and could not be tested in laboratory settings, it cannot be excluded that some of the variation seen in bacterial numbers between cloths were due to small antibacterial effects, however from the results it seems likely that humidity was the most important parameter determining growth and survival of bacteria in the cloths. The package information for cloth no. 15 claimed that "bacteria that come into contact with a humid cloth dies within 12 h", and this claim was clearly not achieved as we observed a several log increase in both *Salmonella* and total viable count over time (Fig. 3). The claims of cloths no. 17 and 18 were to stop odour and mould growth, which were not tested in the present study. The concept of such re-useable cloths is different than antimicrobial single-use wipes, which have been demonstrated to have a bactericidal effect on surfaces both in kitchens models and in the health sector (Røssvoll et al., 2015; Wesgate, Robertson, Barrell, Teska, & Maillard, 2019). In the re-useable cloths, the antimicrobial compound must be retained to impose an antimicrobial effect in the cloth itself, while for the single-use wipes the release of the antimicrobial compound is maximized to improve the killing of microorganisms on the surface that is cleaned.

4.5. Risky practices and safety advice

Exposure to pathogens from cloths probably in most cases is a result of a series of practices which includes 1) contamination of the cloth, 2) storing the cloth in a way allowing growth and/or survival of pathogens, 3) touching the cloth and/or using it to clean food or hand contact surfaces and finally 4) ingestion of pathogens from contaminated hands or food. From a cross-cultural perspective, a cross tabulation of risky combined practices (wiping up meat juices, not changing the cloth and not hanging it up) revealed that 29% of cloth users in Romania and 22% in the UK are especially exposed to risk, while only 7% of Norwegian cloth users and 16% of the total consumer sample present the same risky pattern from cloth usage. In our previous study based on visits to kitchens in several European countries, it was concluded that Norwegian and British consumers had higher awareness of kitchens hygiene practices than consumers from Romania, Hungary, France and Portugal (Møretrø, Nguyen-The, et al., 2021). This reveals a discrepancy between British consumers' general awareness of hygiene practices versus their cloth practices. One possible explanation is that the former study was based on qualitative interviews and observations in a limited number of households, which were possibly not representative of the larger population. Another explanation is that it may be difficult for consumers to transfer general hygiene knowledge into appropriate practices for each and every utensil in the kitchen, as these vary in functionality and water absorption and drying properties. As regards Romania, our results corroborate previous research combining online surveys and observational data, which highlighted a need to improve knowledge and attitudes towards food safety in the Romanian population, and called for interventions to improve consumers' food safety practices at home (Mihalache, Dumitraşcu, Nicolau, & Borda, 2021).

The present study implies that a primary advice to consumers would be that if the cloth has been used for a purpose that leads to high risk of contamination with pathogens, e.g. to wipe up raw meat spills/residues, they should immediately replace the cloth, alternatively use single-use wipes or paper instead of cloths, which may be the cleaning practice with lowest risk in such situations. These practices are already relatively common, as 48% of the European consumers reported using paper or single-use wipes for cleaning meat juice spills and 30% changing the cloth, showing the potential to implement safe practices.

Since it may be difficult for all consumers to be aware of which foods that may contain pathogens and not, advice about storage practices of cloths that reduce rather than increase the contamination levels should also be given. If the cloth is not replaced after use, hanging the cloth to dry will reduce the risk. Hanging the cloth to dry is an easy communicable advice that should be promoted further to reach the 43% of cloth users that do not hang the cloths to dry after use, ranging from 59% in the UK to 22% in Norway. Also increasing the drying time, i.e. the time between use occasions will reduce the risk, as bacteria will die over time, but as drying time will vary between different cloths and the type of usage will vary it is difficult to make a specific advice on drying time. In the present study, the majority of the cloths were not dry after 4.5 h, even when hanging unfolded. However, these cloths were allowed to absorb water to their maximum capacity. Most practical use of cloths will lead to less absorption of water/liquid, as one may typically rinse and wring the cloth after use, and thus reduce drying time. But if the cloth is used several times a day, it is not likely to dry up between use. A recommendation to have multiple cloths so each cloth can dry up between use, may be an option. However, knowing which cloth to use at any time may be complicated to implement in multi-person households. A simple advice may be to always use a fully dry cloth, as dryness is easily perceived with the sense of touch. An additional advice based on the results from the present study may be to choose types of cloths that dry fast. However, as there was no clear correlation between types of cloths and the drying rate, this advice may be difficult for consumers to follow in practice. To our knowledge, choosing cloths that dry fast is not an argument included in advice about cloths provided by food safety authorities and is rarely used as an argument in marketing of cloths. If producers of cloths tested the drying rate of cloths, this may be used as a safety argument in the marketing of cloths and give the consumer the possibility to choose the safest cloths.

Our data did not provide any documentation of a potential effect of antimicrobial re-useable cloths. Based on this and on the fact that the use of unnecessary chemicals should be limited from an environmental viewpoint, antimicrobial cloths should not be recommended. We are not aware of any food safety authorities recommending the use of such cloths.

4.6. Limitations

It should be noted that the discussions and advice proposed in this manuscript were mostly based on the microbiological safety of the cloth. A limitation of the study is that we have not taken into account other factors that may be important for the consumer when choosing a cloth, e.g. cleaning efficacy, cost, design etc. Cleaning efficacy of cloths may be related to food safety, as a high cleaning efficacy may reduce cross-contamination from surfaces/equipment. In a study on the effect of cloth materials on removal and transfer of viruses to different surfaces (Gibson, Crandall, & Ricke, 2012), found that cellulose/cotton cloths and microfiber cloths removed more and transferred less viruses than other cloth materials. Such investigations were out of the scope of this work.

Self-reported behaviour related to food-safety practices has been documented to be overrated compared to observed practices, especially in participants of higher education (Zhang, Zhu, & Bai, 2022). One may therefore consider the estimates of risky practices reported in this study as conservative. Another limitation is that two questions in the survey asked how often one changes the “cloth or sponge”, and what drives the decision for changing the “cloth or sponge”. It is therefore not clear whether consumers thought of cloths and/or sponges when answering these two questions. However, as the reported data included cloth users exclusively, the assumption was made that these answers were relevant to cloths.

Since we anticipated high reduction of *Campylobacter* under dry conditions, we chose to start with a high number of *Campylobacter* to be able to see differences in survival/reduction between cloth types and storage conditions in the laboratory experiments. The starting level (8 log) was higher than what can be expected in most practical situations. Thus, the observed time until viable *Campylobacter* could not be detected was likely longer than in practical situations, however the number of log reductions may still be relevant for risk assessments. The present study did not consider the place of residence of the participants (Sukumaran & Rajani Devi, 2021), nor the kitchen configuration (Mihalache et al., 2022); future research may investigate how cloth practices may vary within countries in relation to such parameters.

5. Conclusions

This paper aimed to map the usage and storage of cloths among European consumers in six countries, and to evaluate how these practices affected survival and elimination of foodborne pathogens, thus affecting the risk of foodborne illness. We found that kitchen cloths are broadly used by consumers in Europe for cleaning food contact surfaces, including wiping up risky spills such as chicken juices. Combined with poor routines of changing the cloth and hanging it to dry, this study reveals that 16% of surface-cleaning cloth users may be at risk of pathogen spreading in their kitchen, with higher occurrence observed in Romania (29%), the UK (22%) and Denmark (14%). Related to representative population samples, this corresponds to an estimated 11%, 7% and 7% of the general population in these countries, respectively. There are large differences between cloths on the market with regard to water uptake and drying rate, and these factors are important for growth and survival of *Salmonella* and *Campylobacter*. Choosing a product that dries rapidly can reduce bacterial numbers, but such an advice may be difficult to follow for consumers as there was no clear pattern between materials of cloths and drying rates. In conclusion, in order to prevent pathogen contaminations from cloth usage, consumers across Europe should be advised to change cloths after using them for meat spills and to always choose a dry cloth.

Declaration of interests

The authors declare no conflict of interest.

CRediT authorship contribution statement

Trond Møretrø: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Valérie Lengard Almli:** Formal analysis, Methodology, Data curation, Writing – original draft, Writing – review & editing, Visualization, Funding acquisition. **Anette Wold Åsli:** Methodology, Investigation, Visualization. **Charlotte Kummen:** Methodology, Investigation, Visualization. **Martina Galler:** Formal analysis, Writing – review & editing, Visualization. **Solveig Langsrud:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition.

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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.2022.109195.

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