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Project title: **A method for the preparation of chicken liver pâté that reliably destroys campylobacters**

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ABSTRACT

The aims of this study were to devise a protocol for the preparation of commercial quantities of pâté that reliably destroyed campylobacters contaminating the chicken liver ingredient. A literature search identified 40 pâté manufacture recipes. Recipes were appraised and stages that were likely to be antimicrobial were assembled to form a new protocol that included washing with organic acid, freeze-thaw and flambé in alcohol. Contaminated livers from organic clearance flocks were obtained directly from slaughterhouses as high-risk material and the effect of each stage of the protocol to *Campylobacter* populations on naturally contaminated livers was determined. Organic acid washing changed the colour of the liver surfaces. However, there were no significant differences between liver surface colour changes when a range of concentrations of lactic acid and ethanoic acid washes were compared by reflective spectrophotometry. Both organic acid washes reduced numbers of indigenous campylobacters by around 1.5 $\log_{10}$ CFU/g at a concentration of 5% (w/v). Liver cooking effectiveness was appraised by thermography and temperature loggers and the use of a Bain Marie was found to more reproducibly apply heat compared with pan-frying. The antimicrobial protocol stages did reduce the numbers of campylobacters, but not significantly if thermal processing was ineffective. Cooking to 63^{o}C was confirmed to be a critical control point for campylobacters in pâté. Organoleptic and sensory assessment of pâté manufactured using the protocol from fresh or frozen livers determined both to be acceptable, with an overall preference for pâté made from frozen livers.

INTRODUCTION

Infection by *Campylobacter* spp. is responsible for the majority of cases of foodborne bacterial gastroenteritis in developed countries (Blaser, 1997). Typically in England and Wales, the annual incidence of infection is around nine cases for each 10,000 of the population. Therefore, in 2012, there were more than 65,000 laboratory-confirmed cases (HPA, 2013), with an annual, seasonal peak of human infections in late spring (Farmer, 2012). However, only one in seven *Campylobacter* infections is reported (Wheeler et al, 1999), and so the disease burden is likely to be significantly higher than the number of confirmed cases. In contrast to the trend of reducing numbers of infections by other foodborne bacterial pathogens such as *Salmonella* and *E. coli* O157, the incidence of campylobacteriosis has increased each year in England and Wales over the last decade (HPA, 2013). Investigations into the sources of campylobacters infecting humans indicated a poultry reservoir (Evans and Sayers, 2000), with molecular typing source attribution studies concluding that *Campylobacter* strains isolated from chicken livers were the most similar to human isolates (Strachan et al, 2012).

A particular concern for the increasing incidence of campylobacteriosis is commercial caterers and restaurants, because if chicken livers are undercooked, large numbers of people can become infected (O'leary et al., 2009; Little et al, 2010; Farmer et al 2012). In Scotland, an outbreak involving 48 people lasted three weeks and occurred after a single restaurant changed the method it used to cook chicken livers (O'leary et al., 2009). The likelihood that chicken livers will be contaminated with campylobacters is high in the UK. In north east Scotland, a retail survey reported that 81% of chicken livers were contaminated (Strachan et al 2012). More recently, more general surveillance across Great Britain reported that 87% of chicken livers purchased at retail were contaminated, with a geometric mean load of 2.2 $\log_{10}$ CFU campylobacters/g liver (Harrison et al, 2013). There are

several reports that campylobacters can internally contaminate livers (Baumgartner et al. 1995; Whyte et al 2006) and associated appendages such as gall bladders and bile ducts (Matasovska et al. 1992). Internal contamination of liver with campylobacters means more than a surface sterilisation is required to render them safe for consumption.

Although it is evident that undercooked chicken livers can cause outbreaks of campylobacteriosis, it has been determined that >70^{o}C for at least two minutes at a liver's core is required to be attained to cook livers safely (Whyte et al, 2006). An important point, raised by Whyte and colleagues (2006), was that undercooked livers were pink and that colouration had consumer appeal. Furthermore it was indicated that, if the livers were cooked for too long, they became unappetising and grey with unfavourable changes in texture. Little et al. (2010) suggested, and O'Leary et al. (2009) unequivocally determined that caterers had been undercooking livers in an attempt to keep them pink and appealing to consumers. At the same time, the imperfect cooking had led to the UK outbreaks of campylobacteriosis associated with the consumption of chicken liver dishes.

The purpose of this study is to decrease the food safety risks associated with the consumption of chicken livers. We report the findings of a thermographic assessment of the temperatures attained during Bain Marie cooking and pan-frying of livers internally and externally. Furthermore, we investigate the distribution of campylobacters throughout poultry livers. In addition, we validate a Bain Marie-based cooking method that reproducibly destroyed campylobacters but kept the livers pink with an appealing texture. Finally, we undertook a step-by-step microbiological assessment and full sensory evaluation of a recipe for chicken liver pâté that was cooked using a Bain Marie to a validated campylobacteriocidal temperature.

MATERIALS AND METHODS

Identification of chicken liver pâté recipes and PROMPT analyses. The chicken liver pâté recipe searches were undertaken by using the Google search engine using the search string "chicken liver pâté recipe". In addition, recipes were sourced from cookbooks by visiting local libraries and bookstores. Initially, each recipe was reviewed and assessed for cooking method, the use of any antimicrobial ingredients and any antimicrobial process stages that might lower the number of campylobacter present in the chicken liver. Any recipe-specific factors that were likely to confound antimicrobial actions were also highlighted. Subsequently, two researchers independently scored the Provenance, Relevance, Objectivity, Method, Presentation and Timeliness of each recipe by assigning a score of between 0 and 5 for each attribute (Open University, 2012). The mean score for both researchers and for each attribute were used as an index of the quality of the recipe, the author and any supplementary information. For inclusion, a mean PROMPT score of three or greater was required (Appendix 1).

Liver sources. For samples requiring microbiological assessment, fresh chicken livers were collected directly from slaughterhouses so that previously-thinned final clearance birds could be selected as those most likely to be colonised with high numbers of campylobacters. Furthermore, direct collection meant confidence that the livers had not been frozen previously and had been only routinely processed to remove gall bladders and bile ducts before cleaning and chilling in slush ice. Livers for human consumption were purchased fresh from a local food store.

Temperature monitoring of cooked livers and Bain Marie cooked pâté. To measure the temperature of chicken livers during pan-frying, infrared thermography was undertaken using a radiometric thermal imaging camera (Fluke Ti25, Norwich, UK). The unit was calibrated by the manufacturer to have a measurement error of <2% of the temperature reading. An emissivity value

of 0.85 was used for all images. The Smartview software program (version 3.1, Fluke) was used to process the raw camera data to thermographic images. Pan-frying was undertaken using butter (10g) and a pan surface temperature of around 100°C, to prevent excessive oxidation of the fat. For the determination of liver surface temperatures during pan-frying, thermographs of liver surfaces were taken after turning surfaces that were cooked for 100 seconds. Internal temperatures of the livers were assessed from thermal images of cut surfaces. Temperatures inside pâté cooked in a Bain Marie were directly monitored using temperature loggers set to record the temperature every minute (Tinytag Plus 2; Gemini Data Loggers, Chichester, UK). One logger was placed in each corner of a square terrine and another was placed in the centre. A scaffold made from matchsticks was used to ensure there was no direct contact between the loggers and the base or sides of the terrine. The loggers were covered with pâté macerate. There was a 1.2cm thickness over the top of the logger.

Liver washing. Livers were washed by immersion of an equal mass of ethanoic or lactic acid, tap water or milk or selected combinations of these wash treatments. The concentrations of organic acid used ranged from 1%-5% (w/v; TABLE 1). The duration of the immersion for organic acids or tap water was two minutes at ambient (21°C) temperature. Soaking in milk was undertaken for one hour at 4°C with periodic agitation every 15 minutes.

Microbiological examination. For each sample of raw liver or cooked pâté, a 25g subsample was generated by chopping if required and then removing small randomly-selected pieces using a sterile teaspoon to ensure that any liquid meat exudate was also sampled. An equal volume of maximum recovery diluent (MRD, Oxoid, Basingstoke, UK) was added to each sample before homogenisation for 1 minute using a stomacher (Model number BA 6021, Seward, UK). *Campylobacter* spp. were enumerated using the ISO 10272 part 2 direct-plating method (International Standards Organisation, 2006) with minor modifications. In brief, 2ml of the initial 1:5 dilution were spread onto six plates of

modified charcoal cefoperazone deoxycholate agar (CCDA, Oxoid CM0739 plus SR0155). The next dilution was a 1:10 and all subsequent dilutions were decimal as described by ISO 10272. All dilutions were made using MRD. 100 µl volumes of the decimal dilutions were plated in duplicate onto CCDA. Incubation was under microaerobic conditions (CampyGen, Oxoid) at 41.5°C for 48 hours

Confirmation of *Campylobacter* spp. was by an inability of five colonies to grow in an aerobic atmosphere when streaked on Columbia Blood Agar (Oxoid) at 41.5°C and a positive oxidase reaction for five colonies when a colony was blotted onto a tissue containing two drops of a 1% (w/v) solution of N,N,N,N tetramethyl-para-phenylenediamine dihydrochloride. In addition, a single colony from each plate was tested serologically for visible agglutination using Dryspot *Campylobacter* (Oxoid) according to the manufacturer's instructions.

Reflective spectrophotometry. Liver surface colour was assessed before and after immersion in tap water, ethanoic or lactic acid for two minutes. Also assessed were immersion in 1% fat milk for one hour without and in combination with the acid and water immersions. Colour measurement before and after treatment was undertaken using a Minolta Chromameter CR400 (Minolta Camera Company Ltd., Milton Keynes, U.K.), according to manufacturer's instructions. Measurements of L* (luminance), a* (red-green), and b* (yellow-blue) values were undertaken in the CIELAB chromatograph as the average of three readings per liver assessed. There were at least two livers assessed per trial, before and after each immersion treatment and the trials were repeated on three occasions using different livers from different flocks.

Sensory analyses. Panel assessors were selected and trained according to British Standard 7667 (BSI, 1993) and received additional training in the assessment of specific pâté characteristics as intensity scales. The descriptors used are listed in TABLE 2. In addition to sensory evaluation, hedonic descriptors of colour likeability of sample, flavour likeability of sample and overall likeability

of sample were scored also. A range of descriptors were selected from previous historic sensory evaluations and provided to the panellists. Thereafter, they discussed the words amongst themselves and decided which words to keep and the additional words they would like to use. All of the descriptors were assessed on a linear sliding scale from soft/smooth/nil to firm/coarse/extreme or in the case of colour from pink to grey-brown. Tasters had a further two training sessions to familiarise themselves with the descriptors and intensities experienced. In each training session, tasters were given samples manufactured in the same way as the experimental material to be tested and a commercial preparation of pâté purchased from a local retailer.

On the day of the test panel, each panellist was given a sample from each of the two pâtés. The samples were randomly coded and supplied to each panellist in a different order. Four different batches of each treatment were assessed within a single morning. The random sample orders, replications and recording of assessment scores were managed using the Fizz software package (Biosystèmes, Couternon, Burgundy, France).

Statistical Analyses. Paired and homoscedastic t-tests, analysis of variance and Tukey's honestly significant difference (HSD) post hoc analyses were undertaken using the SPSS software (Version 21; IBM, Armonk, NY, USA) and used to compare colour data and the $\log_{10}$ numbers counted from the liver samples as appropriate. For all tests, a *P* value of <0.05 was used to determine any significant differences between treatments.

RESULTS

Compilation of a pâté manufacture protocol. A total of 40 different chicken liver pâté recipes were sourced from books and numerous internet websites, including supermarket own websites, celebrity chef websites or cookery blogs. An initial assessment revealed that most recipes suggested cooking livers using a frying pan and then typically, blending in a food processor after cooking. Importantly, the majority of those recipes stated a need to ensure that the pan-fried livers were still pink in the centre. Alternative cooking methods identified included microwaving, poaching and pre-cook blending in a food processor before oven-baking in a Bain Marie. Potential antimicrobial ingredients included alcohol (35/40 recipes); onions or chives, which contain a number of heat-stable antimicrobial compounds (32/40 recipes); garlic, which contains an antimicrobial compound called allicin (30/40 recipes); pepper (26/40 recipes), which contains capsaicin and thyme, which contains the phenolic derivative antimicrobial compound, thymol (20/40 recipes; Appendix 1). However, the majority of the recipes cooked those potentially antimicrobial ingredients prior to their contact with the livers, making it likely the antimicrobial compounds were inactivated. Soaking livers in milk prior to cooking was included in three recipes, soaking in brandy in one recipe, while flambéing in brandy or other alcohol was included in three of the evaluated recipes. Each of those practices was perceived as a likely additional antimicrobial stage, which might result in a reduction to the number of campylobacters. From the twenty two recipes subjected to PROMPT analysis, only nine recipes had an average PROMPT score equal or higher than 3, and only three had an average score that was equal or higher than 3.5. Summaries of the assessment scores are provided as Appendix 1.

Thermal processing. The cooking method for the pâté manufacture protocol was chosen after undertaking thermographic assessment of cooked livers (FIGURE 1). In keeping with the previous observations of other authors (Whyte et al 2006), pan-frying resulted in an uneven heat application. The centres of the pan-fried livers were commonly significantly cooler than the surfaces. Once removed from the pan surface, the livers cooled rapidly as has been previously reported (Whyte et al

2006). We measured a cooling rate of 0.5°C/second on average between 70°C and 45°C. In contrast, cooking using a Bain Marie required around 45 minutes for the core temperature to reach 68°C.

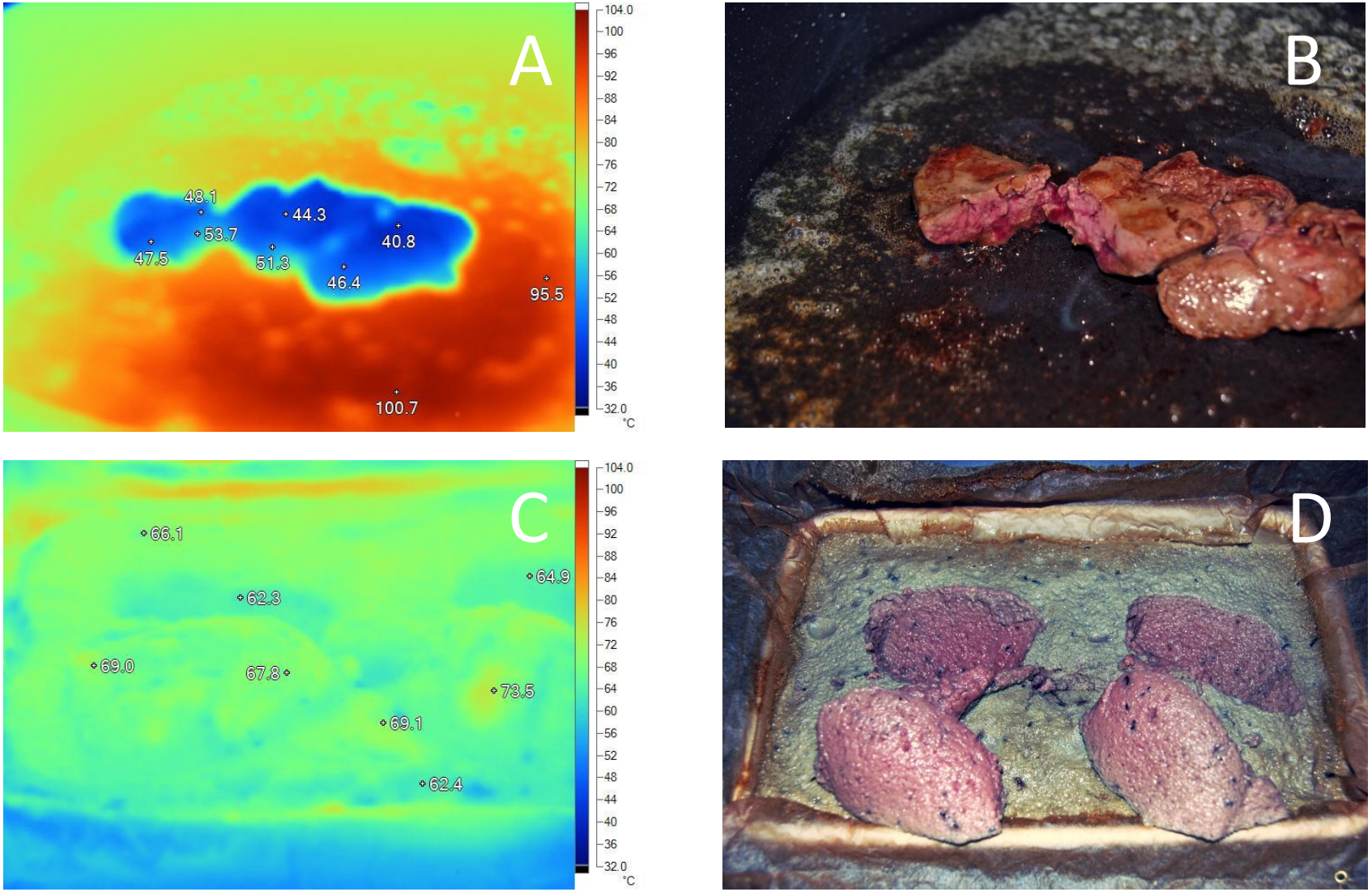

FIGURE 1 Thermographs showing surface and internal temperatures (A and C) and corresponding visible images showing colour and appearance (B and D) after cooking by pan frying in butter on a surface at 100°C for 100 seconds on each side of the liver (A) or in a Bain Marie of boiling water placed in an oven set to 130°C for 45 minutes (B). Both sets of cooked livers were subject to 10-15 seconds of cooling before the thermographs could be taken. The Bain Marie cooked pâté set only after cooling and was subject to rheological movements between image captures.

In the Bain Marie, the longer heating time allowed the core temperature to rise slowly and resulted in an apparent more uniform temperature throughout the mass of the pâté (FIGURE 1C). However, once removed from the oven, the exposed surface of the Bain Marie-cooked pâté also cooled rapidly. The image shown in FIGURE 1C was taken around 10 seconds after removal from an oven set to 130^{o}C. In order to accurately measure the temperature inside the pâté, temperature loggers were placed at the corners and centre of a square terrine and baked with the liver macerate. A typical set of temperature traces is shown as FIGURE 2. There were no significant differences when the temperature records from each logger were compared during the time interval that cooking occurred, or the time interval that the pâté was cooking and cooling (ANOVA, P>0.05). (ANOVA, P>0.05). The most rapid heating was observed to be in the two corners of the terrine closest to the oven fan. The centre of the macerate and the corner of the terrine furthest from the fan had the lowest rate of heating and lowest final temperatures.

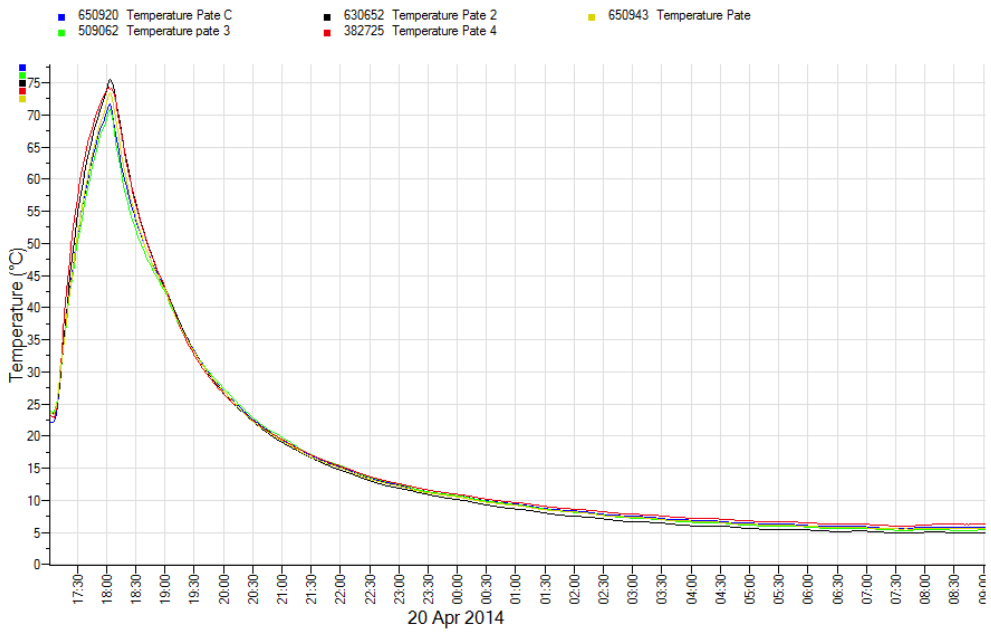

FIGURE 2 The temperatures achieved at the corners (yellow, black, red and green) and centre (blue) of a terrine of macerated livers during baking in a Bain Marie.

Effect of washing. Washing with either of the organic acids assessed, caused changes to the colour of the liver surfaces (TABLE 1). Typically, the liver surfaces were bleached by the acids and there was a reduction in the red component of the colour reading (TABLE 1). Overall, there was no apparent correlation between acid concentration and the degree of bleaching, which may have been a consequence of livers from different flocks having slightly different colours. Cutting into acid-treated livers showed that the bleaching was confined only to the liver surface and extended less than 1mm into the livers (results not shown). There was no significant difference between the colours of acid-treated and control livers after blending (results not shown).

TABLE 1 Colour changes to the surfaces of fresh chicken livers as a consequence of immersion ethanoic or lactic acids of different concentrations. [a]standard error of the mean of six average colour attribute scores.

Treatment	Mean colour component change after treatment (± sem[a])					Overall colour change (ΔE^*_{ab})
	ΔL^*	Δa^*	Δb^*	ΔC^*	ΔH^*	
Water rinse	1.13 ± 0.22	-1.11 ± 0.33	-1.19 ± 0.25	-1.33 ± 0.38	0.93 ± 0.19	2.16 ± 0.27
1% ethanoic acid	5.24 ± 0.57	-2.64 ± 0.41	-1.11 ± 0.50	-2.88 ± 0.52	0.68 ± 0.26	6.15 ± 0.54
2% ethanoic acid	5.62 ± 0.40	-2.43 ± 0.37	-0.20 ± 0.20	-2.39 ± 0.35	0.61 ± 0.17	6.17 ± 0.49
3% ethanoic acid	4.64 ± 0.98	-2.61 ± 0.39	-0.45 ± 0.20	-2.65 ± 0.42	0.33 ± 0.08	5.37 ± 0.53
4% ethanoic acid	4.51 ± 0.45	-1.98 ± 0.17	-0.02 ± 0.31	-1.91 ± 0.15	0.74 ± 0.22	5.00 ± 0.43
5% ethanoic acid	3.19 ± 0.51	-1.11 ± 0.27	0.11 ± 0.20	-1.05 ± 0.31	0.39 ± 0.16	3.44 ± 0.53
1% lactic acid	2.90 ± 0.46	-2.70 ± 0.22	-1.85 ± 0.21	-3.04 ± 0.25	1.22 ± 0.18	4.47 ± 0.37
2% lactic acid	3.26 ± 0.55	-1.64 ± 0.48	-1.34 ± 0.36	-1.94 ± 0.56	0.83 ± 0.24	4.16 ± 0.47
3% lactic acid	2.12 ± 0.30	-1.60 ± 0.38	-0.73 ± 0.41	-1.74 ± 0.47	0.73 ± 0.15	3.00 ± 0.35
4% lactic acid	1.97 ± 0.45	-1.78 ± 0.31	-0.72 ± 0.41	-1.93 ± 0.39	0.73 ± 0.20	3.10 ± 0.26
5% lactic acid	1.59 ± 0.54	-0.96 ± 0.11	0.10 ± 0.08	-0.91 ± 0.12	0.34 ± 0.07	2.08 ± 0.38

Our initial strategy was to reduce the numbers of campylobacters contaminating the livers as quickly as possible, to reduce the likelihood of contamination of the kitchen environment. Therefore, for the initial experiments, chicken livers were subjected to organic acid washes before soaking in milk (FIGURE 3A). However, the organic acid residues led to curdling of the milk and interfered with blood removal and therefore the experiment was repeated using the milk soak stage before the acid soak, with a tap water rinse in-between. The results showed that a wash with a 5% (v/v) solution of lactic or ethanoic acid significantly reduced number of campylobacters on the chicken liver surface,

compared with untreated control or a water rinse (P<0.001; P<0.05, respectively). Similarly, when the acid solution wash was followed by a milk soak, the reduction in *Campylobacter* numbers was significantly greater when compared with untreated control or water rinse for both lactate (P<0.001; P<0.01) and ethanoate (P<0.001; P<0.05), respectively. Typically, the reduction was around one log CFU/g (FIGURE 3). There were no significant differences between any of the different organic acid individual or combination treatments. Immersion of the livers in milk, or water then milk, reduced the numbers of campylobacters on the livers by roughly 0.5 log CFU/g, which was not significant. *Campylobacter* contamination of the milk, or water then milk, treatment livers was midway between the organic acid treatments and the controls and there were no significant differences for the milk treatments when compared to either controls or organic acid treatments.

When the order of the combination treatment was switched from organic acid or water followed by milk, to milk followed by organic acid or water, the observations were that all of the treatments including milk significantly reduced *Campylobacter* numbers when compared with an untreated control (P<0.001). For a milk soak followed by a lactic or ethanoic acid treatment, the livers contained significantly lower numbers of campylobacters compared with milk-only soaked livers (P<0.001; P<0.05 respectively). Furthermore, the combined milk/lactic acid treatment reduced *Campylobacter* numbers compared with a milk/water treatment (P<0.05). There was no significant difference between the two combined organic acid washes.

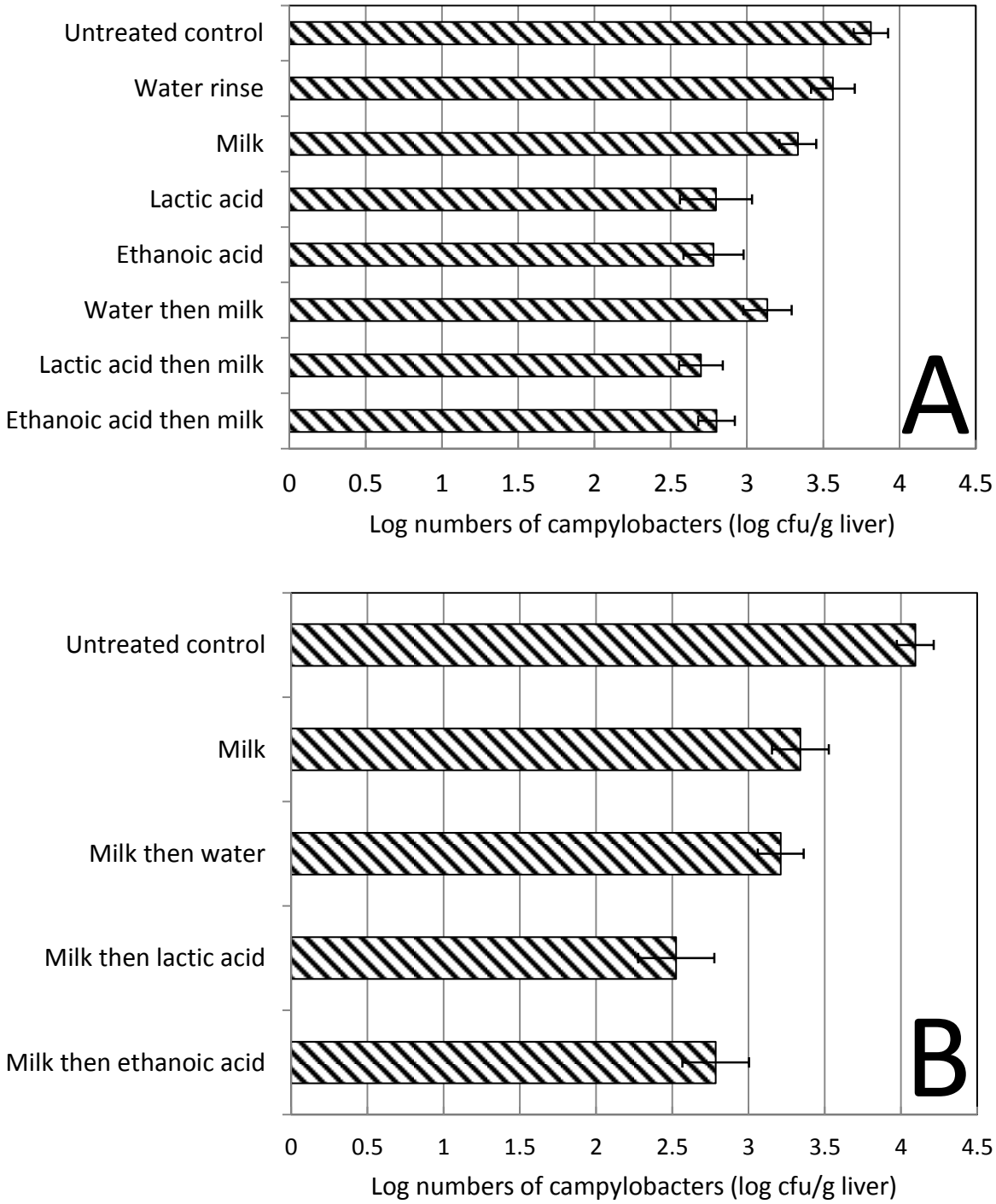

FIGURE 3 (A) The effect of immersing livers in water or organic acid (2 min for each solvent), milk (for 1 hr) or organic acid immersion (2 min) followed by milk immersion (1 hr) on the numbers of campylobacters present on chicken livers. (B) The effect of immersing livers in milk (for 1 hr) followed by immersion in water or organic acid (2 min for each solvent) on the numbers of campylobacters present on chicken livers. For both experiments, final clearance livers were stored chilled at 2^{o}C for 48h before the commencement of each treatment. Error bars are the standard error of the mean log count for both graphs.

Preparation of chicken liver pâté. Pâté was prepared from fresh or freeze-thawed livers so that microbiological and sensory comparisons could be made between the two source materials. After the identification of likely antimicrobial stages and thermographic assessment of the different thermal processing methods, a protocol for the manufacture of chicken liver pâté was assembled.

An illustrated, detailed version of the recipe is provided as Appendix 2. In overview, to remove blood from the livers, 500g were soaked in 500 ml of 1% fat milk containing a crushed garlic clove, two sprigs of bruised thyme, two bay leaves and 1% (w/v) salt. After the soak, the livers were rinsed in tap water and immersed for two minutes in 500ml of store-bought vinegar, which was a 5% (v/v) solution of ethanoic acid. After draining, 50ml of brandy was poured onto the livers, which were stirred to ensure an even coating of alcohol and the alcohol was ignited using a blow torch. The livers were mixed with a chopped clove of garlic and 120g of chopped shallots that had been cooked by frying in a pan containing 50g of melted butter with a surface temperature of 100°C for 6 minutes. Beetroot (10g) was added to the mixture to confer a red cast. The ingredients were liquidised in a blender (Model R2, Robot Coupe Ltd, Isleworth, Middlesex, UK). Whilst blending, five raw eggs and 450g of melted butter were added to the mixture. The mixture was passed through a sieve (0.212 mm mesh; Cole Palmer, London, UK) to remove fat and connective tissue, and cooked in a Bain Marie of boiling water placed in an oven preheated to 130°C. Although 70^{o}C has been previously reported as a safe cooking temperature for pan fried livers, the Bain Marie took much longer to heat the livers and consequently the pâté was baked until the temperature in the core reached 68°C, determined by thermocouple (Model C9007; Comark Instruments Ltd, Norwich, UK).

As was previously reported, campylobacters were present on livers from colonised final clearance flocks at roughly 10^4 CFU/g (Lawes, 2012; Harrison et al, 2013). In general, each stage of the manufacturing protocol reduced the numbers of campylobacter either by an antimicrobial action or by dilution caused by the addition of additional ingredients (FIGURE 4). Freezing and rinsing in

vinegar caused significant reductions in the numbers of campylobacters (Tukey HSD, P<0.05). Non-significant reductions of around one log were observed as a result of the milk soak, with high numbers of up to three log CFU/ml of campylobacters released into the milk during the soak. Flambé in alcohol or blending with an equal mass of butter were relatively ineffective at reducing the numbers of campylobacters per g of liver or pâté (FIGURE 4).

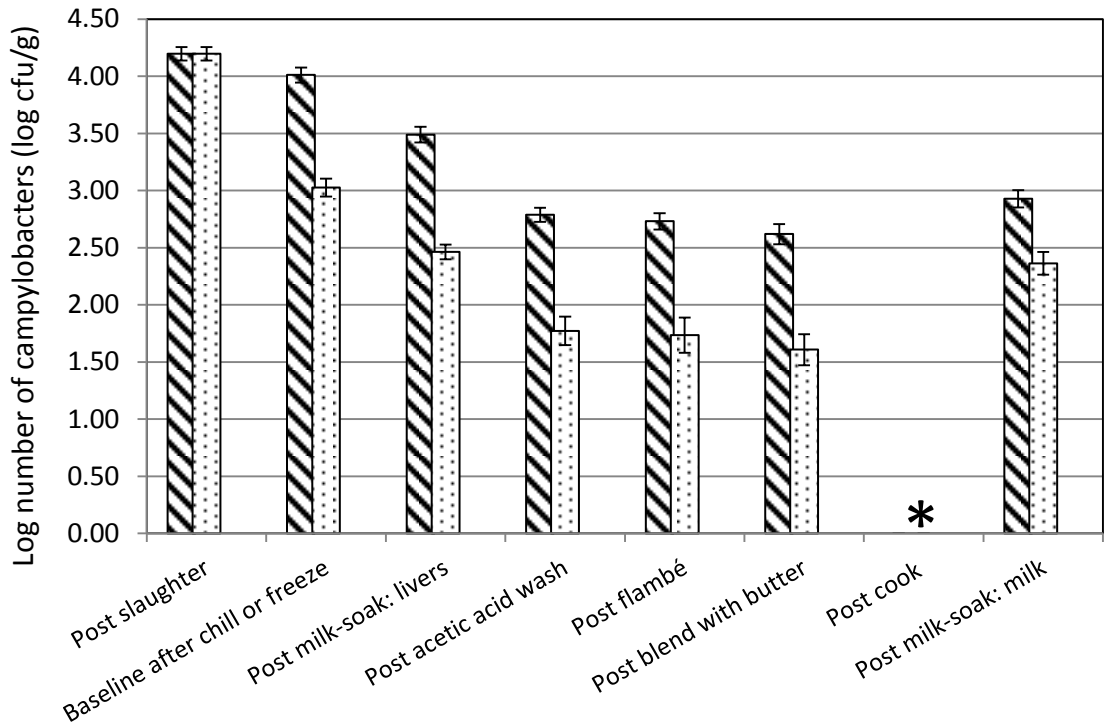

FIGURE 4 The numbers of campylobacters present in chicken livers at each stage of a protocol used for the manufacture of chicken liver pâté. Livers were either stored chilled at 2°C for 48h (diagonal hatch) or frozen to -20°C for 24h and thawed for 24h (speckled dots) before the commencement of pâté manufacture. Error bars are the standard error of the mean log. An asterisk (*) denotes a sample that did not contain campylobacters determined by enrichment.

In order to unequivocally validate cooking in a Bain Marie of boiling water placed in an oven at 130°C for ~45 minutes as a true critical control point, pâté was manufactured under worst case conditions of using fresh livers taken from final clearance flocks without any refrigerated storage, omitting any

milk or acid soaks and without exposure to alcohol, flambé or the inclusion of any herbs. Livers blended with egg and butter and cooked in a Bain Marie as described above did not contain countable numbers of campylobacters (FIGURE 5).

Furthermore, when the pâté was enrichment tested four hours after cooking and after a further 48 hours of refrigerated storage, no campylobacters were isolated (FIGURE 5). Thus, there was no evidence that the Bain Marie cooking caused only sub lethal injuries to the campylobacters and that recovery was possible.

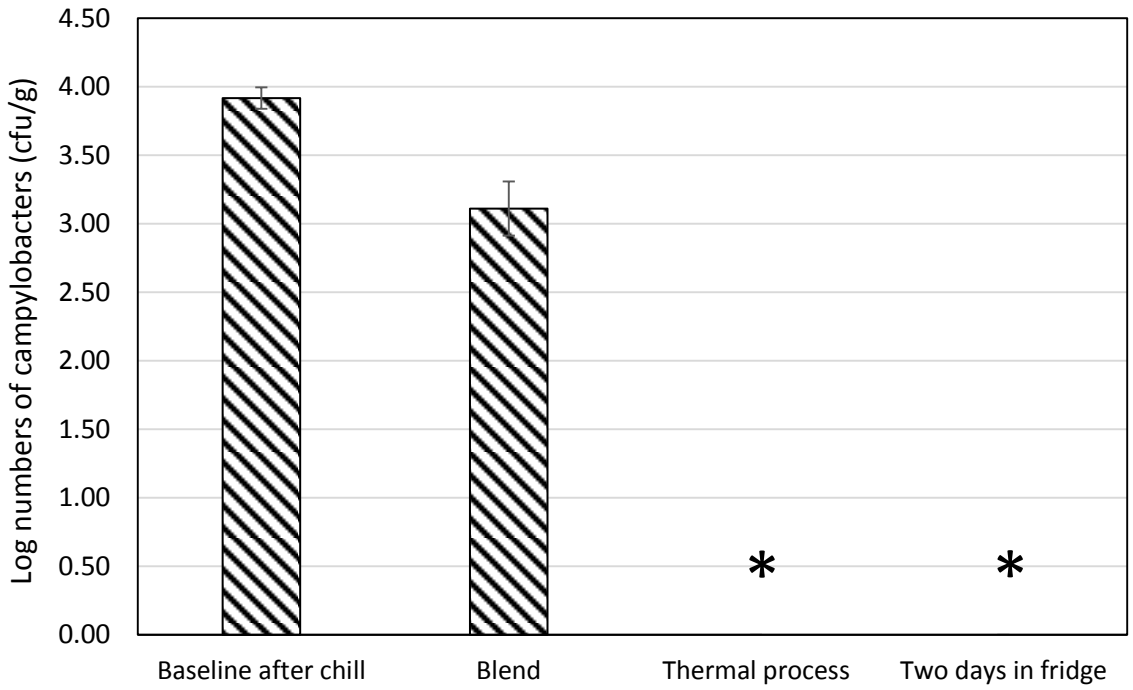

FIGURE 5 The numbers of campylobacters present in chicken livers before and after cooking in a Bain Marie under worst-risk conditions. Fresh livers from final clearance birds were prepared only by blending with an equal mass of molten butter before cooking and refrigerated storage to determine recovery from sub-lethal injury. An asterisk (*) denotes a sample that did not contain campylobacters determined by enrichment.

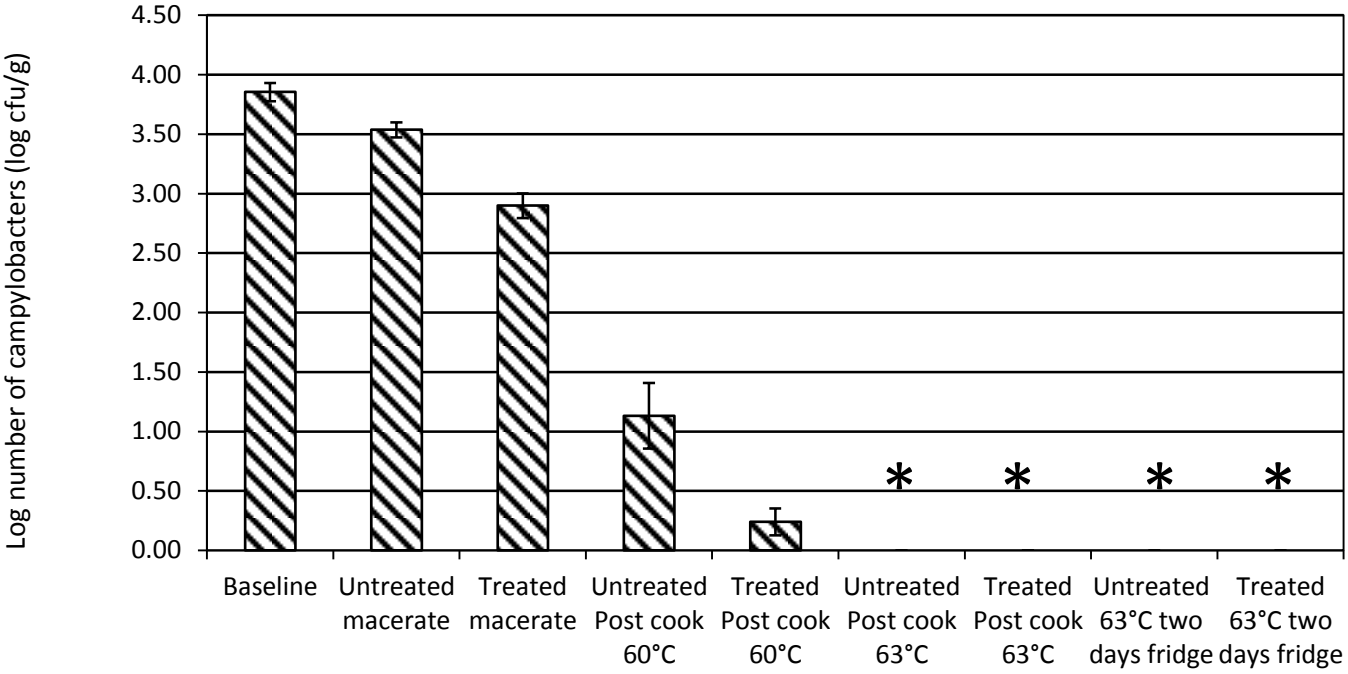

Figure 6 The numbers of campylobacters remaining after imperfect cooking of contaminated livers to 60°C or 63°C. Livers were treated by washing in organic acid and exposed to essential oils (EO) and compared with livers that were not washed in organic acid or exposed to EO to determine if treatment conferred additional safeguards. Error bars are the standard error of the mean log. An asterisk (*) denotes a sample that did not contain campylobacters determined by enrichment.

Experiments to determine if exposure to organic acid and essential oils prior to imperfect cooking showed that there was a significant reduction to the treated macerate compared with the baseline livers. There was no corresponding significant reduction for the untreated macerate. After a 60°C cook, although we observed that the treated macerate had lower numbers of campylobacters compared with the untreated counts, the improved reduction was not significant (ANOVA, Tukey's HSD). No campylobacters were enumerated or detected by enrichment when cooking was to 63°C for either the treated or untreated macerate. There was no evidence of recovery from sub-lethal injury after cooking to 63°C followed by two days of refrigerated storage.

The results of the sensory comparison of pâté manufactured from fresh and frozen livers are summarised in TABLE 2. There were significant differences ($p<0.05$) for the internal colour of the pâté, firmness on eating, strength of the flavour, the amount of residue after eating and acidity for the two treatments. Both pâtés were assessed as acceptable by the taste panel, with a preference for pâté prepared from frozen livers.

TABLE 2 Summary of the results of a sensory evaluation of pâté made from fresh and frozen livers undertaken by a professional taste panel. [a]standard error of the mean of the individual taster scores

Attribute	Total assessment score for pâté made from		*P* value	sem[a]
	Fresh livers	Frozen livers		
Colour on surface	70.5	67.1	0.29	3.25
Colour inside	28.7	47.6	<0.001	3.20
Colour likeability	38.6	40.4	0.63	3.62
Texture on cutting	29.9	30.9	0.8	3.63
On-eating firmness	41.3	22.1	<0.001	4.43
On-eating dissolvability	73.9	75.1	0.72	3.31
Flavour strength	52.7	61.9	<0.001	2.21
Fatty	39.0	37.6	0.62	2.65
Livery	40.4	41.0	0.84	2.68
Acidic	8.4	12.8	<0.05	1.93
Rancid	3.6	4.2	0.45	0.69
Sweet	30.6	30.7	0.94	2.33
Peppery	21.3	22.3	0.7	2.63
Herby	29.9	33.1	0.2	2.55
Salty	22.2	22.8	0.71	1.49
Residue after eating	20.1	7.8	<0.001	2.84
Flavour likeability	44.8	51.0	<0.05	2.65
Overall likeability	36.0	48.6	<0.001	3.05

DISCUSSION

Previously, other studies have reported difficulties in assessing surface temperatures of chicken meat that was fried or boiled (de Jong et al, 2012). Our strategy to circumvent the issue was to use a radiometric device to determine the temperature profiles. Heimann and Jemmi (1995) determined that chicken livers reached around 70°C at the core after two or three minutes of cooking; however an important observation made by Whyte et al, 2006 was that the temperature in the cores and surfaces of livers dropped rapidly when they were no longer in contact with the pan surface. Our contribution to these ongoing studies regarding the effective cooking of liver is that pan frying for 100 seconds each side in a pan with a surface temperature of ~100°C did not always uniformly heat the liver cores to 70°C. Although the thickness of the livers will certainly influence heating and cooling rates, liver pieces of roughly 40g mass still contained blood after cooking (FIGURE 1B). For that reason, the pate manufacture protocol used a Bain Marie for cooking, since it heated the mass of livers more reliably (FIGURE 2). If a probe was used to verify the temperature after cooking, it would be safest to insert it into the centre of the pâté, where the temperature achieved was lowest. We consider that there was likely to be residual kill prior to refrigerated storage during the few hours it took for the pâté to cool to room temperature (FIGURE 2). Potentially the residual heat was the reason that 63^{o}C was sufficient to kill all of the campylobacters when previous workers had reported 70^{o}C or greater was required (Whyte et al, 2006).

A number of different combinations of washing for the livers that involved tap water, milk and organic acid were undertaken. The greatest reductions to the numbers of *Campylobacters* on livers were for the treatments that included the organic acids. Although treatment with milk followed by lactic acid, showed the greatest reduction, ethanoic acid (vinegar) was selected for inclusion into the recipe because the cost of vinegar was significantly less than food-grade lactic acid. Furthermore, in

contrast to lactic acid, vinegar is widely available from food stores. An observation made during treatments undertaken for FIGURE 3A dictated a change to the originally-compiled recipe. If an organic acid wash was applied prior to any milk soak, there was curdling of casein observed on the liver surfaces after the milk was removed. In addition, washing in acid interfered with blood removal from the livers during the milk soak. Post-soak milk was obviously pinker for livers that had not been previously washed in acid (results not shown). We speculate that the acid denatured surface liver proteins and thereby interfered with the osmotic removal of haemoglobin or red blood cells from the livers. In addition, post soak milk was pinker for frozen livers compared with fresh ones, which was most likely a consequence of the more straightforward osmotic removal of haemoglobin from freeze-ruptured erythrocytes.

FIGURE 4 shows the effect of each of the different recipe stages on fresh and frozen-thawed livers contaminated with *Campylobacter*. In general, each stage of the manufacturing protocol reduced contamination of the livers. The benefits of an initial freeze thaw of the livers in terms of reducing contamination by campylobacters are marked, confirming our previous studies (Harrison et al, 2013). In contrast, our observation that initial exposure to brandy followed by ignition of the alcohol was relatively ineffective at reducing campylobacters was surprising. Although previous studies have reported that exposure to 70% ethanol for 1 minute did not reliably surface sterilise livers (Barot et al, 1983), there was a significant amount of heat generated whilst the alcohol burned. One potential explanation for the result was the ignition was typically only for a few seconds, which may have been insufficient to impact significantly on the *Campylobacter* populations. General studies assessing responses to heat have shown that refrigerated storage of chicken meat prior to heat exposure increases resistance to thermal processing (de Jong et al, 2012). Also of potential relevance is motility, which can be an important factor for *Campylobacter* survival by virtue of movement into favourable environments. *Campylobacter* cells were reported by Keum-Il et al, (2007) to move up to 3 mm inside crevices in chicken skin to avoid direct exposure to aerobic

atmospheres. There are reports of *Campylobacter* isolations from the internal tissues of chicken livers and those campylobacters inside the livers may have been protected from the short application of heat.

The addition of butter and eggs during blending essentially doubled the mass of the uncooked pâté. Consequently, we would have expected the numbers of campylobacters per g of material to reduce by half. The real number reductions were of the order of 20%. One possible explanation for this finding was that the campylobacters were present in the form of biofilms or colonies on the liver surface and the shear associated with blending disrupted these structures leaving at least some of the cells viable. There is evidence that campylobacters can bind and interact with specific eukaryotic cell surface receptors (Hu et al, 2006), which may provide the framework for close-knit growth. Traditional microbiological testing using stomaching has been assessed as effective in removing cells from biofilms compared with other methods in aqueous environments (Gagnon and Slawson, 1999). However that does not mean that stomaching removes all of the cells from a biofilm or that it provides an accurate measurement of bacterial numbers from such sources.

It should be kept in mind that the herbs that were included in recipe are not analytical grade reagents and the concentrations of essential oil antimicrobials will vary between different batches of plants (Burt, 2004). Potentially, the issue could result in a variable decontamination performance for the marinade. Garlic contains the short-lived antimicrobial allicin (DeWet, 1999) and there are heat stable antimicrobial compounds in shallots (Rattanachaikunsopon and Phumkhachorn, 2009). Thymol, an essential oil present in thyme, has strong antimicrobial activity, although it is poorly soluble in water (Venkitanarayanan et al, 2013). We observed reductions in the numbers of campylobacters after the milk and herb soak of around one log for both fresh and frozen livers. However, at least part of the reduction was likely to be a consequence of the release of reversibly

bound campylobacters from the liver surface into the milk (Selgas, 1993), rather than true death. Evidence to support that hypothesis, and that the essential oils in the herbs were not able to cause reliable reductions to the numbers of campylobacters was provided by the observation that the spent herb-infused milk used for the soak contained viable campylobacters (FIGURE 4).

There were no significant differences between the numbers of campylobacters in livers treated with organic acid and essential oils and untreated livers when cooking was to 63^{o}C or 60^{o}C. However, these studies provided evidence that the use of a Bain Marie allowed the pâté to cool slowly over the course of a few hours prior to refrigerated storage and there was likely to be residual death of campylobacters during these initial stages of cooling.

As a likely consequence of the increased removal of haemoglobin from pâté made from frozen livers during the milk soak, fresh livers pâté was assessed by sensory evaluation as pinker than pâté from frozen livers. However, the colour difference did not significantly influence colour likeability. Frozen livers pâté was also less firm on eating but assessed as having a stronger flavour. For the descriptors used, the only significant difference between individual flavour traits for the two livers was acidity, with the frozen livers' pâté being more acidic, although there was less residue after eating the pâté made from frozen livers (TABLE 2). Despite the increased acidity, pâté made from frozen livers was preferred for flavour and liked best overall by the nine panellists. A number of the recipes that used a milk soak stated that blood was removed to prevent bitter flavour in pâté and thus the improved blood removal in the freeze-thawed livers may have contributed to the favourable assessment. In addition to the more favourable sensory evaluation for frozen livers, there are additional benefits for freezing in terms of food safety. We have previously reported that freeze-thawing livers reduced the numbers of campylobacters by up to two logs (Harrison et al 2013). Furthermore, de Jong et al

(2012) reported that refrigerated storage of contaminated chicken meat before cooking increased the heat resistance of a number of food borne human pathogens including *C. jejuni*.

In summary, there have been a number of outbreaks of campylobacteriosis that have been traced back to inadequately cooked chicken liver pâté (O'leary et al., 2009; Little et al, 2010; Farmer et al 2012). This study has validated a protocol for commercial quantities of pâté that reliably destroys campylobacters in highest risk livers sourced from final clearance flocks. In addition, the protocol generated pâté that is pink in colour and has other organoleptic properties considered desirable by caterers.

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APPENDIX 1 A SUMMARY OF THE INITIAL APPRAISAL AND A PROMPT ANALYSES OF THE IDENTIFIED RECIPES

Table 3 and Table 4 list the recipes identified from cookbooks and the internet respectively. It became apparent early into the literature search that there was little variation between the typical ingredients and process stages for published recipes for chicken liver pâté. For that reason, Table 5 is a summary of the appraisals of selected recipes. Table 5 aims to provide an overview of typical ingredients and process stages and the likely impact to campylobacter populations contaminating chicken livers.

Table 3 Identification of ingredients containing antimicrobial compounds, and any recipe stages likely to interfere with the action of antimicrobial ingredients (AI). The chicken liver pâté recipes were sourced from cook books.

Recipe source	Likely antimicrobial stages	Confounding factors
(Berry, 1999)	N/A	N/A
(Berry, 2013)	N/A	N/A
(Blashford-Snell and Hafner, 2008)	N/A	N/A
(Hinde and Chitty, 1986) Simple Pâté	Poach the liver in water for 5 minutes Addition of onion, nutmeg, mustard, ground cloves, black pepper	Most AI likely to be denatured before contact with livers.
(Hinde and Chitty, 1986) Chicken liver pate	Post-cook addition of sherry, brandy, thyme, basil, marjoram, garlic, black pepper	Cook lightly "they should remain red inside
(Slater, 2005)	N/A	N/A
(Smith, 1989)	N/A	N/A

Table 4 Identification of ingredients containing antimicrobial compounds, cooking method and any recipe stages likely to interfere with the action of antimicrobial ingredients (AI). The chicken liver pâté recipes were sourced from the internet. The cooking methods were coded as: A, pan frying and blending; B, Blend and bake in a Bain Marie; C, pan frying and blending and bake in a Bain Marie; D, Poaching for 5 minutes on low heat; F, microwaving.

Recipe source	Likely antimicrobial Ingredients	Cooking method	Likely antimicrobial processes	Confounding factors
(All About You website, 2012)	Whisky or brandy, green peppercorns in brine.	A	It is advised to cook livers for 5-10 min until there is no blood left.	Most antimicrobials denatured before contact with livers.
(Allen, 2012)	Port, garlic, onion, thyme and pepper	A		Most antimicrobials denatured before contact with livers. Livers should be left

				pink inside.
(Belcher)	Brandy, garlic, onion, grated zest of 1/2 orange, orange juice.	A	Orange juice and Brandy have direct contact with the cooked liver.	It is advised to wash the livers. Most antimicrobials denatured before contact with livers. Livers should be left pink inside.
(Blanc, 2012)	*Milk marinade. Madeira, port, garlic, shallots, thyme and black pepper.	B	Prolonged cooking time up to one hour.	Most antimicrobials denatured before contact with livers. Low cooking temperature of 70°C.
(Bluebird Tavern restaurant, 2012)	Brandy, onion, spice blend containing cinnamon, clove, anise, fennel, black peppercorn and black pepper.	C	Fried until medium rare and cooked in the water bath for 25 minutes (160 °C oven)	
(Carluccio, 2012)	Brandy, sweet sherry, garlic, sage and parsley and black pepper.	A	Brandy and the sherry have direct contact with pre-cooked blended livers.	Moderate low heat,“still pink in the middle”. Small quantities of alcohol.
(DITTY'S-Home-Bakery)	Whiskey, garlic, onion, thyme, black pepper.	A	Whiskey has direct contact with the liver before cooking.	Moderate low heat. Most antimicrobial from the herbs denatured before contact with livers.
(Eat me Drink me blog, 2007)	Brandy, Marsala, onion, thyme or rosemary, bay leaves and black pepper.	A	Marinade livers for a couple of hours in milk and salt and then wash and dry.	
(Elliott, 2011)	Brandy, garlic, onion and black pepper.	A		Most antimicrobial from the herbs and brandy may be denatured before contact with livers. It is advised that the inside of the livers should still be pink.
(Faulkner, 2012)	Streaky bacon, cloves garlic, onion, brandy, tarragon, black pepper, olive oil.	A	All the ingredients have direct contact with the liver before cooking.	
(Food.com website, 2001)	Brandy, garlic, onion, thyme and black pepper.	A	Thyme, pepper, cream, brandy and melted butter have direct contact with the liver before cook.	
(Food.com website, 2009)	Onion and black pepper.	A		In a blender or food processor, combine liver pieces with the reserved pan drippings, onion, salt and pepper.
(Food:mk website)	Brandy, garlic, tarragon, and black pepper.	A		Most antimicrobials from the herbs and Cognac denatured

				before contact with livers.
(Griffin, unknown year)	Brandy, garlic, onion, mustard powder and black pepper.	A	Cook the livers until golder-brown all over and cooked through.	Onions sautéed before contact with livers.
(Harriot, 2012)	Brandy, garlic, tarragon and black pepper.	A		Most antimicrobial from the herbs and Cognac denatured before contact with livers.
(Hughes, 2011)	Onions, nutmeg and black pepper.	D		
(Hawthorn)	Brandy, Cointreau, Grand Mariner, garlic, zest of orange, juice of orange.	A		
(Lacey, 2012)	Sherry,shallot, nutmeg and Dijon mustard.	A	All the ingredients have direct contact with the liver before cook.	Moderate low heat remove from heat when livers still slightly bloody.
(Law, 2011)	Milk marinade. Cognac or brandy, garlic, shallots, thyme, bay leaf and black pepper.	A	Marinade for up to six hours in thyme and bay. Have the oil in the pan hot enough to smoke Flambé with brandy. Post-cook addition of brandy to parfait	Low cooking time of 30 seconds for each side of liver, so they still pink inside.
(Lebovitz, 2013)	Whiskey, port, or sherry wine, red wine vinegar,onion, cayenne powder and black pepper.	A	Wine vinegar, whiskey have direct contact with the liver at blending stage.	They cook until they are just-cooked through but still pink inside. Remove from heat.
(McKenna)	Brandy, garlic, onions, thyme and mustard seeds.	Cook over a medium heat for 15 minutes, until the livers are fully cooked – there should be no trace of redness, but you don't want a crust to form.	All the ingredients have direct contact with the liver at processor.	
(Microwave-Technologies-Association website)	Sherry, brandy, garlic, onion, dried mixed herbs and black pepper.	F	Cook on HIGH power for 5 minute. Sherry, garlic and onion in direct contact with liver.	
(Ocado website, 2008)	Red wine, chives, thyme and black pepper.	A	Specific mention that can use frozen livers. Livers into boiling butter for four minutes "Livers just cooked through	

			when cut open"	
(OohLookBel blog, 2011)	Milk marinade. Grand Marnier or brandy,balsamic vinegar, garlic, onion and thyme.	A	Marinade the livers in milk and then dry them with the paper towel.	Most antimicrobial from the herbs and cognac may be denatured before contact with livers. It is advised that the inside of the livers should still be pink.
(Oliver, 2013)	Brandy, garlic, shallots, sage, thyme, mace and black pepper.	A	Addition of shallots, garlic, sage. Flambé with brandy.	Most AI denatured before contact with livers. Sage not evenly distributed throughout pate. Vague with regard to cooking temperature. Strong warning not to overcook livers.
(Pépin, 2007)	Cognac or Scotch whisky, garlic, onion and thyme.	A	Cook the livers until they are barely red.	Most antimicrobial from the herbs denatured before contact with livers.
(Pickard, 2012)	Port wine, garlic, shallots, thyme and black pepper.	A	Addition of wine and shallots to pre-cooked for 4 minutes liver and their further cooking to reduce alcohol.	Most antimicrobial from the herbs denatured before contact with livers.
(Prince, 2012)	Brandy, garlic, shallots and thyme.	A	Flambé with brandy.	Most AI denatured before contact with livers. Sage not evenly distributed throughout pate. Vague with regard to cooking temperature.
(Ricket-Hong)	Dry white wine or vermouth, garlic, green onions, dill, rosemary, dry mustard and lemon juice.		All the ingredients have direct contact with the liver before cooking. Bring to a boil and cook, uncovered, until the liquid is gone	
(Schwartz website)	Brandy or sherry and tarragon.	A	Livers are cooked for 10 minutes and then with brandy for further 2 minutes.	Most antimicrobial from the herbs denatured before contact with livers.
(Serious Eats website, 2008)	Brandy, shallots, sage and black pepper.	A	Soak the chicken livers in the brandy for 3 to 4 hours in a cool place; do not refrigerate. Drain the livers and reserve the liquid.	
(Shields, 2012)	Rum or brandy, garlic, shallot, bay leaf and mace powder.	A		Bay and mace boiled in cream before contact with livers. Onions sautéd before contact with livers. Alcohol in brandy evaporated before contact with livers.

				Cook the liver such that still pink inside.
(Smith, 2001)	Cognac, garlic, thyme, mustard powder, ground mace and black pepper.	A	All the ingredients have direct contact with the liver before cook during blending.	
(Smith, 2005)	Brandy, garlic, onion, thyme, rosemary and black pepper.	Fry in the pan for 5 min, then with brandy and then mix in the processor.	Cooked over a high heat with brandy.	Most antimicrobials from the garlic, herbs and Cognac may be denatured before contact with livers.
(Spar website, 2013)	Cognac, garlic, thyme, mustard powder and nutmeg.	A		Most antimicrobial from the herbs and Cognac denatured before contact with livers.
(Stewart, 2010)	Onion, thyme and cayenne pepper.	A		Most antimicrobial from the herbs and Cognac denatured before contact with livers.
(Tesco realfood website)	Garlic, shallots, thyme, dried cranberries and black pepper.	A	It is advised to thoroughly cook the livers.	
(The Washington Post website)	White wine or vermouth, garlic,scallions, mustard, dill, rosemary and lemon juice.	A	Add herbs and brown the livers for 10 minutes, then add wine, bring to boil and cook for 8 to 10 minutes.	
(Woman and Home website)	Brandy or port, garlic, onion andbay leaves.	A	Following the frying add the brandy and port, and flambé.	Most antimicrobial from the herbs denatured before contact with livers.

Table 5 A PROMPT analysis of selected recipes (with duplicate/substantially equivalent recipes omitted)

Recipe source	Attribute	PROMPT analyses notes	PROMPT score
(All About You website, 2012)	P	Author not identified.	1
	R	Most antimicrobials in whiskey/brandy and peppercorns are cooked and therefore denatured/ have reduced activity before any contact with the livers.	1
	O	No obvious bias for the All About You website. No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	Livers cooked until there is no blood left (5-10 min), clearly stated to not overcook them, but no reference to leave them pink in the middle.	2
	P	A list of all required ingredients was provided. Information regarding nutritional values included. Clearly laid out recipe- each stage was numbered. No pictures, photos or video, but the wording was	4

		descriptive enough to be easy to follow.	
	T	Present on the website in 2012, relatively new recipe, however it does not contain anything that is new or novel.	1
		Average PROMPT score	2.33
(Allen, 2012) Hello Magazine website	P	Clearly-identified author with appropriate background/training/experience, a celebrity chef.	5
	R	Most antimicrobials in the garlic, shallots, thyme, port and pepper are cooked and therefore denatured/ have reduced activity before any contact with the livers.	1
	O	No obvious bias for HELLO magazine website. Product placement for Kerrygold butter. No branded products for complementary foods such as the recommended accompanying wine.	2
	M	Livers cooked for 2–4 minutes on each side, clearly stated that they should still be slightly pink inside.	1
	P	A list of all required ingredients was provided. No nutritional information included. Clearly laid out recipe- each stage was numbered. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	Present on the website in 2012, relatively new recipe, however it does contain potential AI ingredients, which are however cooked before contact with livers.	2
		Average PROMPT score	2.5
(Belcher) Delicious Magazine website	P	Clearly-identified author.	3
	R	Most antimicrobials in the garlic and onion are cooked and therefore denatured/ have reduced activity before any contact with the livers. Orange juice and brandy added to cooked livers, but only in a small volume and brandy suggested as an optional ingredient.	1
	O	No obvious bias for Delicious magazine website. No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	Livers cooked for 2–3 minutes until browned, clearly stated that they should still be slightly pink inside.	1
	P	A list of all required ingredients was provided. Information regarding nutritional values included. Clearly laid out recipe- each stage was numbered. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	No date provided for the recipe. Recipe contains potential AI ingredients, which are however cooked before contact with livers.	2
		Average PROMPT score	2.66
Blanc (2013) BBC website	P	Clearly-identified author with appropriate background/training/experience, a celebrity chef.	5
	R	Most antimicrobials in the garlic, shallots, thyme, madeira, port and pepper are cooked and therefore denatured/ have reduced activity before any contact with the livers.	1
	O	No obvious bias for either the BBC website (which has no advertising) or Raymond Blanc. No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	Milk marinade will remove roughly half of the reversibly-bound	4

		campylobacters Low cooking temperature of 70°C. But prolonged cooking duration of up to one hour. Possible to set an objectively-measured target temperature setting for the oven.	
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered. No pictures, photos or video, but the wording was descriptive enough to be easy to follow.	4
	T	No date provided for the recipe. Fairly novel use of a Bain Marie for cooking could be used to promote food safety compared with pan frying.	3
		Average PROMPT score	3.67
(Bluebird Tavern restaurant, 2012)	P	Recipe provided on the well-established restaurant website with the author identified only by name.	3
	R	Most antimicrobials in the onions are cooked and therefore denatured/ have reduced activity before any contact with the livers. Spices are cooked together with the livers.	1
	O	Website which has no advertising. No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	The method includes cooking livers in the pan until medium-rare and then in the later stages using Bain Marie for 25 minutes at 160°C. The temperature of pate during cooking not tested.	4
	P	A list of all required ingredients was provided. Information regarding nutritional values included. Clearly laid out recipe- each stage was numbered. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	Date for the recipe provided (November 2012). Fairly novel use of a Bain Marie which combined with pan cooking could be used to promote food safety compared with pan frying.	4
		Average PROMPT score	3.5
(Carluccio, 2012) The Arburturian website	P	Clearly-identified author with appropriate background/training/experience, a celebrity chef.	5
	R	Most antimicrobials in the garlic, sage and pepper are cooked together with the livers and therefore have reduced activity.	1
	O	Website which has no advertising. No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	The method includes frying the livers in the pan until still “pink in the middle”, blending onto a rough paste and again cooking with the butter over a low heat. The temperature of pate during cooking not tested.	2
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	Date for the recipe provided. Recipe contains potential AI ingredients, which are however cooked with livers.	2
		Average PROMPT score	3.16
(DITTY'S-Home-Bakery)	P	Recipe provided on the bakery website, however no information regarding author provided.	2

	R	Most antimicrobials in the onion, thyme, garlic and pepper are cooked and therefore denatured/ have reduced activity before any contact with the livers.	1
	O	Bakery own website with no advertising. No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	The method includes frying the livers in the pan until still "pink in the middle" (approx. 8 minutes), blending onto a smooth paste. The temperature of livers during cooking not tested.	1
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	No date provided for the recipe. Recipe contains potential AI ingredients, which are however cooked with livers.	2
		Average PROMPT score	2.5
(Eat me Drink me blog, 2007)	P	Recipe adapted from well known cookery book "The Silver Spoon".	2
	R	Most antimicrobials in the onion, thyme, bay and pepper are cooked and therefore denatured/ have reduced activity before any contact with the livers.	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	The method includes frying the livers in the pan for a total of approximately 5 minutes so possibly "pink in the middle" and then chopping with knife onto a rough paste. The temperature of livers during cooking not tested.	1
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	Date for the recipe provided. Recipe contains potential AI ingredients, which are however cooked with livers.	2
		Average PROMPT score	2.5
(Elliott, 2011) Not Quite Nigella website	P	Clearly-identified author with appropriate background/experience, a celebrity chef and the recipe adapted from known cookery book "A Cook's Guide" by Donna Hay.	5
	R	Most antimicrobials in the onion, garlic and pepper are cooked and therefore denatured/ have reduced activity before any contact with the livers	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine. Elliot's cookery book advert.	3
	M	The method includes frying the livers in the pan for 2-3 minutes and then for further 1 minute with added brandy. Clearly stated that the livers should "still be pink inside". The temperature of livers during cooking not tested.	1
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered and supported by the pictures. The wording was descriptive and easy to follow.	5
	T	Date for the recipe provided and fairly novel (2011). Recipe contains potential AI ingredients, which are however cooked with livers.	2
		Average PROMPT score	2.83
(Food.com	P	Recipe provided on the well known cookery website with the chef	2

website, 2001)		identified only by name.	
	R	Most antimicrobials in the onion, garlic, thyme and pepper are cooked and therefore denatured/ have reduced activity before any contact with the livers.	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	The method includes frying the livers in the pan for 5-10 minutes and then using a blender. The temperature of livers during cooking not tested	2
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered. Information regarding nutritional values included. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	Date for the recipe provided (2001). Recipe contains potential AI ingredients, which are however cooked with livers.	2
		Average PROMPT score	2.66
(Food.com website, 2009)	P	Recipe provided on the well-known cookery website with the chef identified only by name.	2
	R	Not clear whether onion is raw or pre-cooked when added to pre-cooked livers.	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	The method includes frying the livers in the pan for 6-8 minutes and then using a blender. The temperature of livers during cooking not tested	2
	P	A list of all required ingredients was provided. Each stage of the recipe was numbered; nevertheless the wording was not descriptive enough. Information regarding nutritional values included. One picture of the final product included.	3
	T	Date for the recipe provided (2009). Recipe contains potential AI ingredients.	2
		Average PROMPT score	2.5
(Food:mk website)	P	Unknown author.	1
	R	Most antimicrobials in the shallots, garlic, thyme and pepper are cooked and therefore denatured/ have reduced activity before any contact with the livers	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	The method includes stages using Bain Marie for 1 hour and 20 minutes at 150°C. The temperature of pate during cooking not tested by the thermometer but the needle is used to check the middle of the pate.	4
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered. No pictures, photos or video, but the wording was descriptive enough to be easy to follow.	4
	T	No date provided for the recipe. Fairly novel use of a Bain Marie and prolonged time of cooking (over 1 hour) could be used to promote food safety compared with pan frying.	4
		Average PROMPT score	3.16
(Griffin) BBC website	P	Clearly-identified author with appropriate background/experience, a celebrity chef and the recipe adapted from known cookery book “A Cook’s Guide“ by Donna Hay.	5
	R	Most antimicrobials in the onion, garlic are cooked with the livers and therefore have reduced activity.	1

	O	No obvious bias for either the BBC website (which has no advertising) or Angela Griffin. No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	The method includes frying the livers in the pan and then using a blender. The temperature of livers during cooking not tested, it is however advised that the livers should be cooked through.	2
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered. No pictures, photos or video, but the wording was descriptive enough to be easy to follow.	4
	T	No date provided for the recipe. Recipe contains potential AI ingredients.	2
		Average PROMPT score	3.16
(Harriot, 2012) My Kitchen Table website	P	Clearly-identified author with appropriate background/experience, a celebrity chef.	5
	R	Alcohol is reduced before added to liver pate. Not clear whether garlic and tarragon is raw or pre-cooked when added to blended livers.	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	4
	M	The method includes frying the livers in the pan for 3-4 minutes so they still “slightly pink inside”. The temperature of livers during cooking not tested.	1
	P	A list of all required ingredients was provided. Each stage of the recipe was numbered, but not clear how or if to cook the herbs. One picture of the final product included.	3
	T	No date provided for the recipe. Recipe contains potential AI ingredients.	2
		Average PROMPT score	2.66
(Hawthorn) The Kitchen Company website	P	Clearly-identified author with appropriate background/experience, a celebrity chef.	5
	R	Garlic, pepper, orange zest and juice are blended raw and mixed with cooked livers.	2
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine. Clear advertising for Phil Hawthorn.	3
	M	The method includes frying the livers in the pan and then using a blender. The temperature of livers during cooking not tested, but advised to check if the livers are “cooked/brown evenly, all the way through”.	3
	P	A list of all required ingredients was provided. Clearly laid out recipe. One picture of the final product included, the wording was descriptive enough to be easy to follow.	3
	T	No date provided for the recipe. Recipe contains potential AI ingredients which are added raw to the liver pate.	3
		Average PROMPT score	3.16
(Hughes, 2011) Cooking Channel website	P	Clearly-identified author with appropriate background/experience, a celebrity chef.	5
	R	Most antimicrobials in the onions are cooked before added to livers and therefore have reduced activity.	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5

	M	The method includes poaching the livers in the pan for 5 minutes and then using a blender. The temperature of livers during cooking not tested.	3
	P	A list of all required ingredients was provided. Clearly laid out recipe. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	No date provided for the recipe. Recipe contains potential AI ingredients which are cooked before contact with livers.	1
		Average PROMPT score	3.16
(Lacey, 2012) Canal Cook blog	P	Clearly-identified author, known blogger.	3
	R	Most antimicrobials in the shallot are cooked before added to livers and therefore have reduced activity.	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine. Adverts present on the website.	4
	M	The method includes frying the livers in the pan for 5-7 minutes and then using a blender. The temperature of livers during cooking not tested and it is advised to cook the livers until "there is no pink outside", but mentioned that the livers cooked in this way were still bloody inside.	2
	P	A list of all required ingredients was provided. Clearly laid out recipe. Two pictures of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	Date for the recipe provided. Recipe contains potential AI ingredients which are cooked before contact with livers.	2
		Average PROMPT score	2.66
(Law, 2011) A Table for Two blog	P	Clearly-identified author, a contestant of Master Chef Australia.	3
	R	Most antimicrobials in the garlic and shallots are cooked and therefore denatured/ have reduced activity before any contact with the livers, however bay leaf and thyme are added raw to a milk marinade.	3
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine.	5
	M	Milk marinade will remove roughly half of the reversibly-bound campylobacters and contain thyme and bay leaf that contain essential oils additionally effecting Campylobacter numbers. The livers are cooked for 30 seconds and advised to stay "pink in the middle" but then mixed with brandy and ignited.	4
	P	A list of all required ingredients was provided. Clearly laid out recipe. No pictures included, but the wording was descriptive enough to be easy to follow.	4
	T	No specific date provided for the recipe, but blog entry dated for 2011. Recipe contains potential AI ingredients from which some are added raw in a milk marinade.	3
		Average PROMPT score	3.66
(Lebovitz, 2013) David Lebovitz blog	P	Clearly-identified author with appropriate background/experience, a celebrity chef.	5
	R	Most antimicrobials in the onion are cooked and therefore denatured/ have reduced activity before any contact with the livers, however vinegar, liquor, cayenne are added raw to a blender.	2

	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine. Advertising for Phil Hawthorn, other chefs and products.	3
	M	The method includes frying the livers in the pan and then using a blender. The temperature of livers during cooking not tested and it is advised to cook the livers until “they are just cooked and still pink inside”.	2
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered and supported by the pictures. The wording was descriptive and easy to follow.	5
	T	Date for the recipe provided. Recipe contains potential AI ingredients which are partially cooked before contact with livers.	2
		Average PROMPT score	3.16
(McKenna) Red website	P	Clearly-identified author with appropriate background/experience, a celebrity chef.	5
	R	Most antimicrobials in the onion, garlic and thyme are cooked and therefore denatured/ have reduced activity before any contact with the livers.	1
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine. Advertising for other products.	3
	M	The method includes frying the livers in the pan over a medium heat for 15 minutes and then using a blender. The temperature of livers during cooking not tested. It is advised that livers should be fully cooked and there should be “no trace of redness”.	2
	P	A list of all required ingredients was provided. Clearly laid out recipe- each stage was numbered and one picture of the final product included. The wording was descriptive and easy to follow.	4
	T	No date provided for the recipe. Recipe contains potential AI ingredients which are partially cooked before contact with livers.	1
		Average PROMPT score	2.66
(Microwave-Technologies-Association website)	P	Unknown author.	1
	R	Antimicrobials in the onion, garlic, herbs and pepper are mixed with the livers directly before cooking.	2
	O	No branded ingredients were used. No branded products for complementary foods such as the recommended accompanying wine. Advertising for MTA products.	3
	M	All ingredients are mixed with the raw livers before cooking. The method includes cooking the livers for 5 minutes in the microwave on high power setting and then using a blender. The temperature of livers during cooking not tested.	3
	P	A list of all required ingredients was provided. Clearly laid out recipe. The wording was descriptive and easy to follow.	3
	T	No date provided for the recipe. Recipe contains potential AI ingredients which are mixed with the livers before cooking.	2
		Average PROMPT score	2.33
(Ocado website, 2008)	P	Author not identified, however book source given.	3
	R	Most antimicrobials in the chives, thyme andwineare cooked together with the pre-cooked livers and might have reduced activity.	2
	O	No branded ingredients were listed in the recipe. No branded products	2

		for complementary foods such as the recommended accompanying wine in the actual recipe. Advertising for the Waitrose and several branded ingredients in conjunction to recipe (“recipe shopping list”).	
	M	Livers cooked for 4 minutes until browned and for further up to 4 minutes with the addition of other ingredients until they are just cooked.	2
	P	A list of all required ingredients was provided. Information regarding nutritional values not included. Clearly laid out recipe- each stage was numbered. One picture of the final product included, the wording was descriptive enough to be easy to follow.	4
	T	No date provided for the recipe. Recipe contains potential AI ingredients that are added to pre-cooked livers.	2
		Average PROMPT score	2.5

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APPENDIX 2 A RECIPE FOR CHICKEN LIVER PÂTÉ THAT IS FREE FROM CAMPYLOBACTERS

Ingredients:

568 ml (1 pint) of vinegar
450g (1lb) of chicken livers (pre-frozen and then thawed)
568 ml (1 pint) of milk
Two bay leaves
Five sprigs of fresh thyme
15g (½ oz) of boiled beetroot
Two cloves of garlic
120g of shallots
50ml (2 fluid oz) of brandy or Cognac
Five medium sized eggs
450g of spreadable butter
Salt and pepper

Ingredients required for the preparation of chicken liver pâté that is free from campylobacters

Method:

1. There is no need to trim the livers to remove sinew or connective tissue. These types of preparations can contaminate the work area with campylobacters, which can then cross contaminate to other foods. The livers are blended and passed through a sieve later in the recipe, which removes the connective tissue from the final product.
2. Bruise two sprigs of thyme and tear a bay leaf into eight pieces and add them to a large oven-proof bowl. Crush one clove of garlic and roughly chop 50g of shallots (there is no need to peel either) and also add those to the bowl. Thyme, bay, garlic and shallots contain natural antimicrobial compounds called essential oils, which can reduce the numbers of campylobacters present on chicken livers. Add 15g (½ oz) of salt and the 568 ml of milk to the bowl and stir until the salt has dissolved. Place the livers into the milk and transfer to a refrigerator to soak in the milk and herbs for at least one hour. Wash work surfaces with hot soapy water to clean any splashes of milk that landed on the surfaces when placing the livers. Splashes can potentially contain campylobacters, which can cross contaminate other foods that may be consumed without cooking. After the milk is removed from the refrigerator, it will be pink from the blood removed from the livers. Blood can give the pâté a bitter taste.

Livers soaking in milk under refrigeration

3. Using a sieve, separate the milk from the livers and allow the livers to drain for two minutes before rinsing them under a running tap to remove the last traces of milk. To prevent contamination of the kitchen environment, the bowl and sieve should be washed in hot, soapy water to remove any traces of milk. Return the livers to the cleaned bowl. As before, clean up any splashes with hot soapy water to ensure there is no cross contamination to other foods. Pour all of the vinegar onto the livers and allow them to soak for two minutes with occasional mixing to ensure all of the liver surfaces are exposed to the vinegar. Using a sieve, pour the vinegar off, and allow the livers to drain inside the sieve for two minutes. The livers may look a little pale after the vinegar wash, but if you slice open one of the livers, it will show the colour change has affected only the outer surface of the liver. If the livers are contaminated with campylobacters, the majority will be on the liver surface and the vinegar wash will remove a high proportion of any contamination that is present.

Livers after soaking in milk before rinsing in tap water

4. Pre-heat the oven to 130°C.

5. Peel and chop the remaining garlic and shallots. Melt 30g (1 oz) of butter in a pan and add the garlic, shallots and the leaves from two sprigs of thyme. Cook for two or three minutes until the shallots soften and begin to turn brown. Transfer the contents of the pan to the food processor.

Cooked onions

6. Add 400g of butter to the pan and set it on a low heat to melt the butter. Spreadable butter contains a far lower percentage of saturated fat compared to traditional butter.

Melt, but do not oxidise (burn) the butter

7. Wash the oven-proof bowl thoroughly, and return the livers to it. Add the cognac and mix the livers around to coat their surfaces with the alcohol before igniting the bowl contents using a blowtorch or the heat from a gas ring. Exposure to alcohol before ignition will also reduce the numbers of campylobacters on the livers, as will the heat generated by igniting the alcohol. After ignition, the remaining cognac components adds flavour to the livers.

Rinse and drain the livers before adding the brandy and igniting

8. Transfer the livers and the beetroot into the food processor containing the softened shallots and herbs and commence blending. Add the five eggs, one at a time, over a period of five minutes whilst continuously blending.

Cooked and prepared ingredients prior to blending

9. Add two teaspoons of salt and a teaspoon of freshly ground black pepper to the blending livers.

10. Gradually add the 400g of melted butter to the processor over two or three minutes whilst blending continuously. If the butter is added too quickly, the fat may congeal and not disperse evenly through the blended livers.
11. Line the base and sides of a one-litre volume terrine with greaseproof paper that has been softened by scrunching under a running tap. Leave an overlap of paper of a little larger than the width of the terrine.
12. Boil a kettle of water for use in the Bain Marie.
13. Transfer the blender contents into a fine mesh sieve (2 mm hole size or finer) and using the back of a ladle, push the livers through the sieve into the bowl. Connective tissue and sinew will be left behind in the sieve. Dispose of any remnants carefully and wash all equipment that has been used thoroughly in hot soapy water.
14. Pour the bowl contents into the paper-lined terrine and fold the trailing end of greaseproof paper over the top of the pâté. Place the terrine inside a roasting tray and place into the pre-heated oven. Fill the tray with boiling water to ¾ of the height of the terrine. It is important the water is boiling. Cover the roasting tray with a piece of loosely-wrapped aluminium foil

A lined terrine filled with uncooked pâté

15. Cook for 45 minutes then measure the temperature in the centre of the pâté using a temperature probe. If the temperature is hotter than 68°C, then the pâté is cooked and can be removed from the oven. If the centre is lower than 68°C, then return the pâté to the oven until the temperature in the centre hits 68°C.
16. Remove the pâté from the Bain Marie and leave it to cool at room temperature for an hour before refrigerating overnight to harden the butter and firm up the pâté.

Pâté being cooked in a Bain Marie of boiling water

17. Remove the greaseproof paper from the top of the pâté and place the terrine in a tray of boiling water for two minutes. After two minutes, the pâté can be carefully lifted out of the terrine using the paper lining and placed on a chopping board.
18. The greaseproof paper can be removed by careful peeling and the pâté can be trimmed using a sharp knife to remove any discoloured (brown) areas.
19. Once trimmed, the remaining butter should be melted with the leaves from the remaining thyme and some roughly crushed black peppers. A pastry brush should be used to coat the pâté with a thin coating of the infused butter. The butter coating prevents the surface of the pâté from oxidising and discolouring again.
20. If it has been cooked according to the instructions and careful cleaning has been undertaken to prevent contaminated the kitchen environment, the pâté will not contain any campylobacters. Consequently, the pâté can be stored in a refrigerator at 4°C for up to five days. After five days, spoilage might become a concern and so if the pâté is required to be stored for longer periods, freezing is recommended.

A check of the temperature in the core of the pâté is important to make sure it is properly cooked and won't make people ill.

Pâté that is cooked under controlled conditions in a Bain Marie to 68^{o}C is pink inside and does not contain any *Campylobacter* bacteria that can cause food borne illness