

**Risk Assessment Studies
Report No. 63**

Microbiological Hazard Evaluation

**MICROBIOLOGICAL QUALITY OF
ROAST MEATS WHEN THEY ARE
KEPT AT AMBIENT
TEMPERATURE FOR A
PROLONGED PERIOD OF TIME**

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Centre for Food Safety
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EXECUTIVE SUMMARY

Chinese-style roast meats, also called siu-mei, are popular local dishes available in Chinese restaurants and siu-mei shops. During the production of roast meats, bacteria are killed by the high temperature of roasting. However, after roasting, roast meats may be re-contaminated with bacteria from food handlers and the environment, during handling, cutting and packing of roast meats, etc. In order to ensure food safety, roast meats, after preparation, also require proper storage time and temperature control, to minimise any growth of pathogenic micro-organisms and to prevent the formation of toxins by bacteria. Locally, it is not uncommon to see roast meats being hung and displayed in storefront windows in some food businesses for a period of time at room temperature. To understand the effect of such traditional practice on the microbiological quality of roast meats, this study was conducted to assess the changes in the microbiological quality of roast meats during display at room temperature.

Roast pork, barbecue pork (BBQ pork), roast duck and roast goose were sampled from eight food businesses which voluntarily participated in the study during August and September 2019. These businesses included three individual retail shops, three shops from three store chains and restaurant chains, as well as two shops from two supermarket chains. Food handlers of these businesses were requested to keep freshly prepared roast meats in their premises for up to eight hours. Samples were collected at the start of display as well as at four hours, six hours and eight hours after the start of display. At the start of display, food handlers from the supermarkets were requested, in line with their usual practice, to chop the freshly prepared roast meats into pieces, wrap with cling film (known

as “chopped samples”) and keep them for a required period of time at ambient temperature. On the other hand, food handlers from other retail stores and shops were requested to chop roast meats into pieces only at the moment of sampling (known as “unchopped samples”). Bacteriological parameters and water in food available for supporting microbial growth (water activity [a_w]) of the samples were measured to assess the changes of these values throughout the period of display.

Results of the study reveal that roast meats, before being chopped into pieces, do not favour rapid bacterial growth. This finding is in-line with some overseas studies. These results suggest that the current trade practice of hanging and displaying the whole pieces of roast meats in storefront windows of siu-mei shops and restaurants for a period of time without temperature control is unlikely to increase food safety risk. However, when handling roast meats, food handlers should continue to observe good hygienic practices to prevent roast meats from being contaminated with pathogenic microbes such as *S. aureus*.

On the other hand, results of the study reveal that bacteria can grow rapidly on the surfaces of the meats when freshly prepared roast meats are chopped into pieces. Hence, businesses providing chopped and wrapped roast meats should display the products under temperature control or sell the products within four hours, preferably within two hours after chopping. Furthermore, results also showed that during the eight-hour display, the a_w of the samples wrapped in cling film in general increased which had a positive effect on the growth of bacteria.

Conclusion

The study results showed that after eight hours of hanging and displaying whole pieces of roast meats in storefront windows, there were no remarkable increase in their bacterial count. Hence, the local traditional practice of displaying and selling roast meats is unlikely to have a remarkable increase in food safety risk. However, bacteria may grow rapidly on roast meats that have been chopped into pieces and displayed in packaged forms because once chopped, the surfaces no longer protect the roast meat from rapid bacterial growth. Hence, food businesses should avoid displaying roast meats for more than four hours without temperature control, and if chopped roast meats in package forms are for sale, it is preferable that they are sold within two hours.

Advice to public

- If you purchase roast meat which are chopped at the moment of purchase, consume them within four hours after purchase.
- If you purchase packaged chopped roast meats which have already been displayed on a food display counter, consume them as soon as possible or keep them under refrigeration.

Advice to trade

- Prepare smaller batches of roast meats several times through the day to reduce the displaying time of roast meats.
- Food businesses that chop roast meats upon purchase should limit the displaying time at room temperature to less than four hours and remind consumers to consume the chopped roast meats within four hours.
- When food businesses choose to sell chopped roast meats in package

forms at room temperature:

- they should sell the products preferably within two hours after chopping and limit the time of sale to less than four hours after preparation;
- they can include an advisory to remind consumers to consume the chopped roast meats or keep them refrigerated as soon as possible.
- Food handlers should wear disposable gloves when handling ready-to-eat food. Discard gloves when damaged, soiled, or when interruptions occur in the operation.
- Food handlers should wear clean and light-coloured outer clothing or protective overalls. If clothes become soiled during food preparation, change or clean them as necessary.
- Food handlers should wear masks during food handling. Discard the masks when damaged, soiled or after prolonged use.

Microbiological Quality of Roast Meats when They are Kept at Ambient Temperature for a Prolonged Period of Time

OBJECTIVES

The purpose of the study is to assess the changes in the microbiological quality of roast meats displayed at ambient temperature for a period of time, and where appropriate, provide advice to the trade and the public on the safe storage and handling of roast meats kept at ambient temperature.

INTRODUCTION

2. Chinese-style roast meats, also called siu-mei, are popular local dishes available at Chinese restaurants and siu-mei shops. It is generally believed that during the production of roast meats, the high temperature of roasting would kill all bacteria on the meats. However, roast meats may be re-contaminated with bacteria during subsequent handling (e.g. packing, delivery, display and cutting) before being consumed by consumers. Being protein-rich foods and good sources for bacterial growth, meats are usually regarded as potential hazardous food. Hence, it is logical to expect that bacteria should grow rapidly on roast meats when displayed at ambient temperature.

3. Potentially hazardous food is food that requires temperature control to minimise the growth of any pathogenic micro-organisms that may be present and to prevent the formation of toxins by them. According to Food Hygiene Code published by the Food and

Environmental Hygiene Department (FEHD)ⁱ, when displaying potentially hazardous food, operators of food premises should display the food at 4°C or below, or at 60°C or above because bacteria including pathogens are unable to grow (or grow slowly) at these temperatures.¹

4. Besides temperature, time can also be used as a means to ensure food safety because bacteria take time to grow to high enough numbers to cause food poisoning. According to the U.S. Food Code, the total time that a ready-to-eat potentially hazardous foodⁱⁱ can be kept out of temperature control is four hours.² The Food Hygiene Code of FEHD also states that a ready-to-eat potentially hazardous food may be displayed or stored at ambient temperature for a period of not more than four hours. As a general guidance (also known as the “two-hour/four-hour rule”), if potentially hazardous food has been displayed at ambient temperature (i.e., temperature > 4°C and < 60°C):-

- for more than four hours, it should be discarded;
- for more than two hours but less than four hours, it should be used before the four hours limit is up but should not be returned to the refrigerator; and
- for less than two hours, it can be refrigerated for use later or used before the four hours limit is up.

5. If roast meats are potential hazardous food, they must be kept under temperature control or must observe the “two-hour/four-hour rule”. Yet, it is not uncommon to see roast meats being hung and displayed in storefront windows for a prolonged period of time without temperature

ⁱ The FEHD has published a set of food hygiene and safety standards in the form of a "Food Hygiene Code" to help operators of food business better understand the inspection standards on licensed food premises as well as the best practices in meeting the standards.

ⁱⁱ Now renamed as “Time/Temperature Control for Safety Food” in the Food Code 2017 version.

control (i.e., at ambient temperature for over two or four hours). In fact, the prolonged display/storage was identified as one of the potential factors contributing to microbiological hazards in a previous risk assessment study on siu-mei and lo-mei.³

6. The growth of bacteria including the pathogenic bacteria on roast meats is determined by a number of physical factors such as temperature, salinity value (salt content), water activity (a_w), pH and so on. Each type of bacteria has an optimum temperature, salinity, a_w and pH for growth. For example, the limits of physical factors for the growth of *Staphylococcus aureus*, one of the pathogens of concern in roast meats, and enterotoxin production are summarised in Table 1.⁴ Each factor, if not at optimum, can be a hurdle to microbial growth, and hurdles originating from different factors can be combined for retarding microbial growth.⁵

Table 1. Limits for growth of *S. aureus* and enterotoxin production when other conditions are near optimum⁶

Factor	Growth		Toxin production	
	Optimum	Range	Optimum	Range
Temperature (°C)	37	7 – 48	40 – 45	10 – 48
pH	6 – 7	4 – 10	7 – 8	4.5 – 9.6
Water activity	0.98	0.83 – >0.99 (aerobic)	0.98	0.87 – >0.99 (aerobic)

7. Previous studies on roast meats, such as roast pork and roast duck, have identified some hurdles that allow roast meats to be displayed safely, with proper hygienic practices, at ambient temperature for a prolonged period of time.^{7,8,9,10,11} For example, roast ducks are usually dipped in a malt and vinegar mixture and air dried before roasting. Seasoning for roast pork usually contains salt, sugar, and vinegar. In general, vinegar

can lower the pH value of roast meats.⁸ Air drying as well as addition of salt and sugar can lower a_w of food, and hence reduce the availability of water for bacterial growth.⁸ Roasting can further reduce a_w as well as eliminate bacteria of meats.

8. Overseas food safety authorities have also conducted some studies on safe preparation and handling of roasted meats. In summary, research and microbiological testing (e.g. monitoring the growth of certain pathogens) of roasted meats found that, if prepared and handled in certain specific ways, roast meats do not support rapid bacterial growth and roasted duck can be left on display, at ambient temperatures, for up to 22 hours while roasted pork can be on display for up to seven hours.¹²

9. As regards the recommended display/storage time of roast meats at ambient temperature, studies emphasised the importance of a range of hygienic practices that must be met by food handlers, such as avoiding human contact, and preventing the products on display from gaining moisture, etc. (Box 1)^{13,14,15}

Box 1. Excerpt on recommendations by Department of Health, Victoria, Australia, on preparing Chinese-style roast duck and displaying Chinese-style roast meats¹⁴

Preparing Chinese-style roast duck

- Dip the duck in boiling water containing vinegar.
- Hang the duck to dry in the cool room for no longer than six hours.
- Check that the core temperature of the duck does not reach more than 25°C throughout the drying process.

Displaying Chinese-style roast meats

- Ensure the display area is not enclosed to allow air into the display area.
- Ensure there is enough space in the display area to allow for all of the meats to be hung far enough away from each other so that they are not touching each other or any of the other meats on display.
- Carry the meats using a hanging hook, rather than by touching the surface of the meats.

10. Some of these recommendations may also be applied locally to reduce the microbiological risk of roast meats left on display at ambient temperature. However, it is understood that differences in handling practices of roast meats between local and overseas food businesses may exist. In addition, local consumers may sometimes leave roast meats at room temperature after purchase for consumption at a later time. As such, this study may help to assess the local situation regarding the changes in the microbiological quality of roast meats displayed/stored at ambient temperature for a prolonged period of time.

SCOPE OF STUDY

11. This study aims to assess the changes in the microbiological quality of roast meats displayed at ambient temperature for a prolonged period of time and where appropriate, provide advice for the storage of roast meats at ambient temperature.

12. As the preparation procedures and handling practices of roast meats may vary from one shop to another, eight food businesses, ranging from small individual shops to chain stores (i.e., store/restaurant and

supermarket chains), were invited to participate voluntarily in this study with a view to obtaining information that represents the common ways of preparing and handling roast meats on the market. These eight businesses included three individual retail shops, three shops from three store/restaurant chains (two restaurants and one retail shop) as well as two shops from two supermarket chains.

13. Three types of roast meats (i.e., roast pork, BBQ pork, and roast duck/goose) from the participating food businesses were taken for bacteriological testing in order to assess the changes of various bacteriological parameters when roast meats were stored at ambient temperature for a prolonged period of time (i.e., up to eight hours for the experimental purpose). In addition, information on handling practices of roast meats by food handlers of each participating food business was also collected.

METHODOLOGY

Sampling

14. Between August and September 2019, samples of roast pork, BBQ pork, and roast duck/goose were taken from the eight food businesses by health inspectors and researchers of the FEHD.

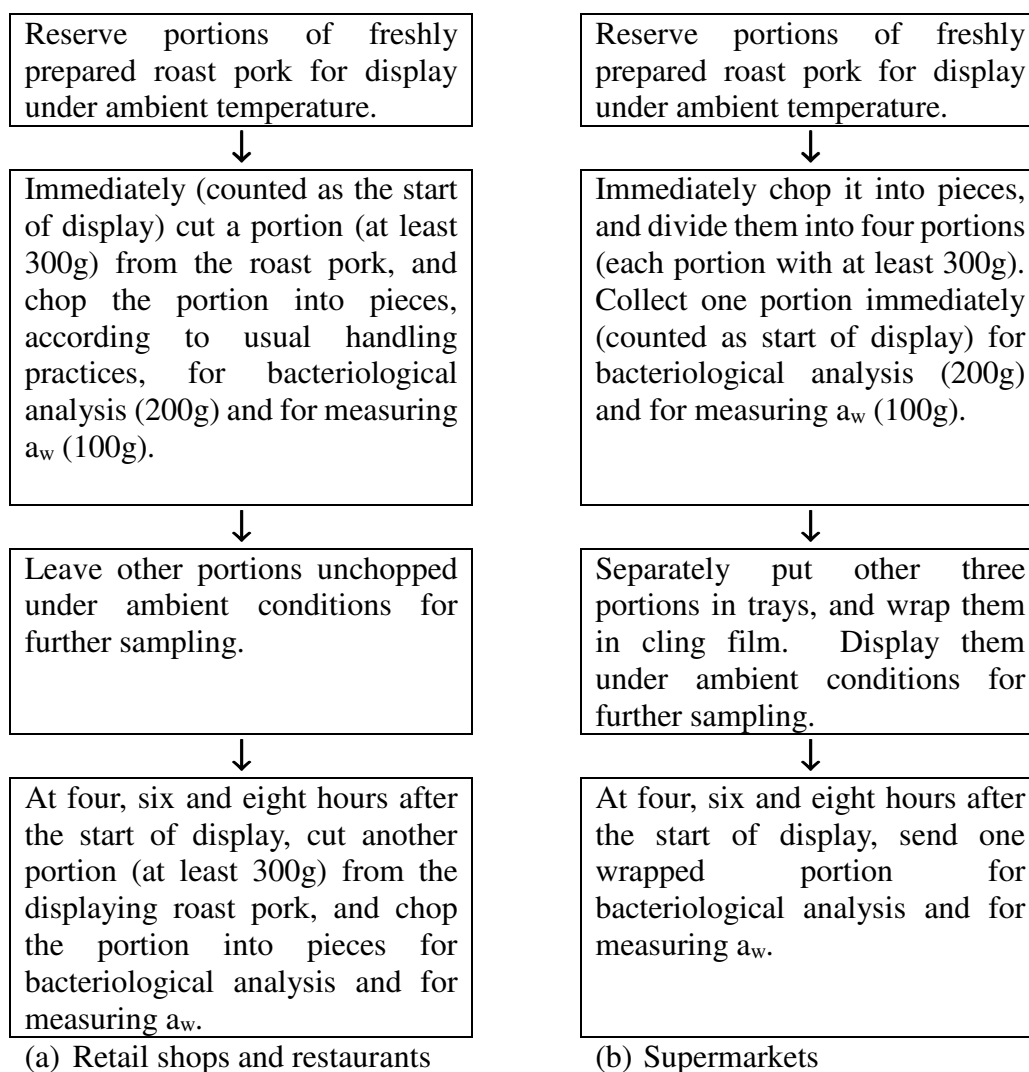
15. The study simulated the real-life situation in which food handlers from the supermarkets, at the moment of collecting the first sample, were requested to chop freshly prepared roast pork reserved for display under ambient conditions into pieces. A portion of the pieces (at least 300 g) was then collected immediately for bacteriological examination. The rest

of the pieces were then divided into three portions (each with at least 300 g), separately put in trays, wrapped in cling film, and displayed at ambient temperature (Figure 1). BBQ pork and roast duck/goose were treated and sampled in the similar way. For ease of discussion, samples taken from supermarkets were referred to as “chopped samples”.

16. As regards samples taken from the retail shops and restaurants, food handlers were asked to reserve freshly prepared roasted pork for display under ambient conditions. At the start of display, a portion (at least 300 g) was cut from the roast pork. The portion was immediately chopped into pieces according to their usual handling practices, and collected for bacteriological examination. After displaying for four, six and eight hours, another portion (at least 300 g) was cut from the roast pork and chopped into pieces for bacteriological examination (Figure 1). BBQ pork and roast duck/goose were treated and sampled in the similar way. For ease of discussion, samples taken from individual shops and restaurants were also referred to as “unchopped samples”.

17. Besides, every time during sample collection, a 100 g sample was also taken from the respective roast meat for measuring a_w . Each sample was put in a plastic box in which a corner of the lid was cut open to prevent condensation, if any.

Figure 1. Procedures of taking roast pork samples at (a) retail shops, restaurants, and (b) supermarkets (BBQ pork and roast duck/goose were treated and sampled in the similar way)



Laboratory analysis

18. After sampling, all samples, except those destined for the measurement of a_w , were immediately stored at 4°C or below, and were delivered to the Public Health Laboratory Services Branch of the Centre for Health Protection (CHP), Department of Health on the next day after sampling. Aerobic colony count (ACC), *Escherichia coli* count as well as *Staphylococcus aureus* and other coagulase-positive staphylococci

count (*S. aureus* count) were used to reflect the microbiological quality and safety of roast meats. For samples destined for a_w measurement, they were immediately delivered to the Food Research Laboratory (FRL) after sampling.

19. The enumeration of ACC in samples was performed using bioMérieux TEMPO Aerobic Count (AC) kits. *E. coli* count in samples was performed using the AOAC Official Methods 991.14 (Revised: March 1998) (PetriFilm Method). *S. aureus* count was enumerated according to Method MFLP-21 Health Products and Food Branch, Ottawa (2004).

20. Water activity refers to the amount of water available in food for microbial growth, and is expressed as the ratio of partial vapour pressure of water in food to the partial vapour pressure of pure water (ranges from 0.1-0.99) at the same temperature. Most pathogens cannot grow in food with an a_w below 0.85.¹⁶ Water activity values of roast meats were determined using an AwTherm Water Activity Meter (Rotronic, Huntington, NY) at 25°C. To measure the a_w of a sample of roast meat, the sample was first chopped into small pieces. A sample cup was then filled with the chopped pieces to no more than half full, ensuring that the bottom of the cup was completely covered. For roast pork and roast goose/duck samples, the a_w values of the skin and meat portions of the samples were separately measured using the same sample preparation procedure. The a_w values of the surface and meat of BBQ pork were not measured separately because previous trial examination by FRL showed that their a_w values were similar.

Information on handling practices

21. A food handler from each participating food business was interviewed to obtain information on the procedures for the preparation as well as handling practices of the roast meats.

Result analysis

22. The hygienic quality and microbiological safety of the roast meats were assessed in accordance with the Microbiological Guidelines for Food (the Guidelines).¹⁷ The changes of bacterial counts and a_w values of the roast meat samples during display were evaluated.

Hygienic quality - ACC and E. coli

23. ACC is the total number of bacteria found in food. It includes those naturally occurring and those as a result of contamination. ACC is an indicator of quality but not safety. The level of ACC in food depends on the type and duration of processing that the food has received during production as well as how the food is handled and stored thereafter.¹⁸

24. *E. coli* is a bacterium commonly found in the gastrointestinal tract of humans and warm-blooded animals. It is commonly used as an indicator organism to reflect the hygienic quality of food. Its presence in food generally indicates direct or indirect faecal contamination. In general, substantial number of *E. coli* in food suggests a general lack of cleanliness in handling and improper storage.¹⁷

25. The ACC and *E. coli* results were assessed against the criteria listed in Table 2. These criteria were extracted from the Guidelines.

Table 2. ACC and *E. coli* criteria used in this study

	Microbiological quality		
	Result (colony-forming unit (cfu/g))		
	Satisfactory	Borderline	Unsatisfactory
ACC [30°C /48 hours]			
• Food category 14. Cooked meat products that may be displayed for sale at ambient temperature for a limited period of time e.g. siu-mei and lo-mei	<10 ⁵	10 ⁵ -<10 ⁶	≥10 ⁶
Hygiene indicator organisms			
<i>E. coli</i>	<20	20 - ≤10 ²	>10 ²

Remark: For ACC, the detection limit is 100 cfu/g. For *E. coli*, the detection limit is 10 cfu/g.

Microbiological safety – S. aureus count

26. *S. aureus* is one of the common food poisoning microorganisms in Hong Kong. The most common way of contamination of food is by contact with food handlers' hands, especially in the cases where the food is handled subsequent to cooking, and once contaminated with *S. aureus*, prolonged storage without refrigeration allows *S. aureus* to grow to high numbers and form enterotoxins. Since the toxins are heat stable, the incriminated food may also cause food poisoning even if it is further heat treated.¹⁷ Roast meats are foods that require considerable handling after roasting but without subsequent cooking, and may be displayed at ambient temperature for a prolonged period of time, allowing *S. aureus* to multiply and produce toxins which cause illness. Although staphylococcal enterotoxins can also be produced in food by some other coagulase-positive staphylococci, e.g. *S. intermedius*, most coagulase-positive staphylococci which cause foodborne illness are *S. aureus*.

27. *S. aureus* count (as *S. aureus* and other coagulase-positive staphylococci) was assessed in this study to see whether *S. aureus*, if present, could grow to high levels or not during storage under ambient conditions. The results were assessed against the criteria listed in Table 3, extracted from the Guidelines.

Table 3. *S. aureus* criterion used in this study

Criterion	Result (cfu/g)		
	Satisfactory	Borderline	Unsatisfactory: potentially injurious to health and/or unfit for human consumption
<i>S. aureus</i> and other coagulase-positive staphylococci	< 20	20 - $\leq 10^4$	$> 10^4$

Remark: The detection limit of the test for *S. aureus* and other coagulase-positive staphylococci is 10 cfu/g.

RESULTS

Hygienic quality – ACC and *E. coli* count.

28. The ACC of the roast meats (including “unchopped samples” and “chopped samples”) after displayed for eight hours did not seem to be related to or depended on the initial ACC of the roast meats reported at the start of display (Figure 2). In other words, a sample with a relatively high ACC may not end up with a corresponding high final ACC, and *vice versa*. In addition, the changes in the ACC during the eight-hour display were different among the samples; for example, some samples showed a fall in the ACC during the first four hours and an increase in another four hours while some showed an increase during the first four hours, a fall in another two hours and then an increase again in the last two hours.

29. The results, however, showed that bacteria grew much slower in the “unchopped samples” than that in the “chopped samples”. Bacterial growth was reported in eight out of 18 “unchopped samples” after displayed for eight hours, ranging from a 1.5-fold to a 60-fold increase. For the other 10 “unchopped samples”, the number of bacteria either remained the same or decreased. The “unchopped sample” (BBQ pork) from the individual shop A showed the greatest bacterial growth (i.e., increasing from 12,000 cfu/g to 600,000 cfu/g, a 60-fold increase).

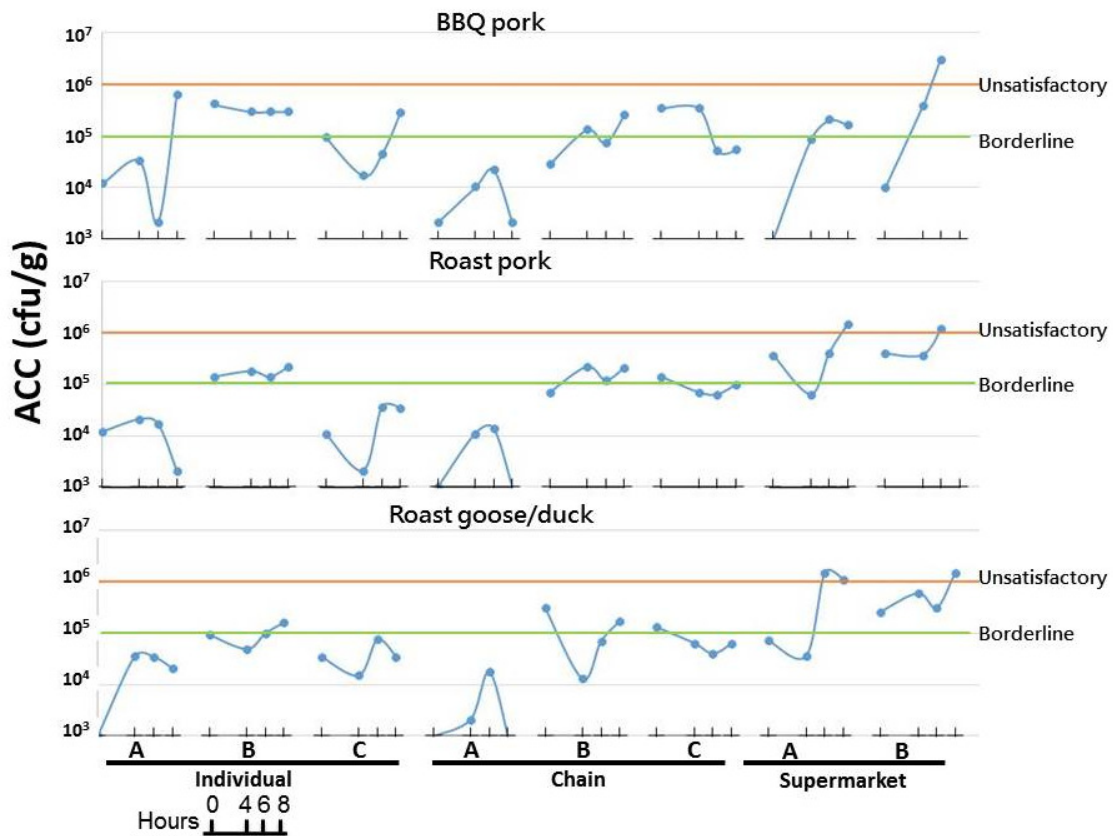
30. For the “chopped samples”, bacterial growth was observed in all six samples, ranging from a 3-fold to a 293-fold increase during the eight-hour display. The chopped BBQ pork sample from supermarket B showed the greatest bacterial growth during the eight-hour period of display, with the ACC increasing from 9,900 cfu/g to 2,900,000 cfu/g (i.e., an increase by around 293-fold).

31. At the start of display, the ACC of all “chopped samples” were similar to that of some of the “unchopped samples”, and there were no samples (taking both unchopped and chopped samples into consideration) with the ACC of unsatisfactory results. However, after the eight-hour display, the ACC of five (out of six) “chopped samples” were of unsatisfactory results (with the ACC ranging from 1,100,000 cfu/g to 29,000,000 cfu/g) while no “unchopped samples” were of unsatisfactory results, indicating that bacteria in the “chopped samples” multiplied at a much faster rates to high numbers.

32. As regards the presence of *E. coli* in roast meats, all samples, except two, taken during the eight-hour period of display from the eight businesses were found to be satisfactory (i.e., samples with *E. coli* < 20

cfu/g). Only one BBQ pork sample and one roast duck sample collected at the start of display from the individual shop B were found to contain *E. coli* at levels of 20 cfu/g and 40 cfu/g (i.e., levels considered to be a borderline between satisfactory and unsatisfactory) respectively; however, *E. coli* of these two samples from subsequent sampling were less than 20 cfu/g. In other words, the growth of *E. coli* during the eight-hour display was not detected in all samples.

Figure 2. Change of ACC in roast meats stored under ambient conditions



Remark: The scale above each store/restaurant on X-axis corresponds to the time points 0 hour, 4 hours, 6 hours, and 8 hours. A base-10 log scale is used for the Y-axis. $ACC \geq 10^6$ cfu/g is considered unsatisfactory in terms of microbiological quality. $ACC \geq 10^5$ cfu/g and $< 10^6$ cfu/g is considered borderline in terms of microbiological quality. “Individual”: Individual shop/restaurant; “Chain”: Chain store/restaurant; “Supermarket”: Supermarket stall. For samples reported to contain < 1000 cfu/g, the assumed ACC level is 999 cfu/g for plotting the graphs. The ACC of BBQ pork sample and roast pork sample collected from supermarket B after displayed for 8 hours were discarded due to sampling errors, resulting in exceptionally low ACCs.

S. aureus count

33. *S. aureus* (as indicated by *S. aureus* count) was detected in all three types of roast meats taken from the individual shop A, the individual shop B, and the shop from store chain B during the eight-hour display (Figure 3). All these samples were “unchopped samples” and the growth of *S. aureus* in these “unchopped samples” was slow, ranging from a 0.3-fold increase to a 37-fold increase.

34. At the start of display, the average initial *S. aureus* counts of :

- BBQ pork was 20 cfu/g (ranging from 10 cfu/g to 60 cfu/g);
- roast pork was 30 cfu/g (ranging from 10 cfu/g to 90 cfu/g); and
- roast goose/duck was 34 cfu/g (ranging from 10 cfu/g to 180 cfu/g),

assuming that those reported with *S. aureus* < 20 cfu/g contained 10 cfu/g, the detection limit of the test.

35. At the end of display, the average final *S. aureus* counts of :

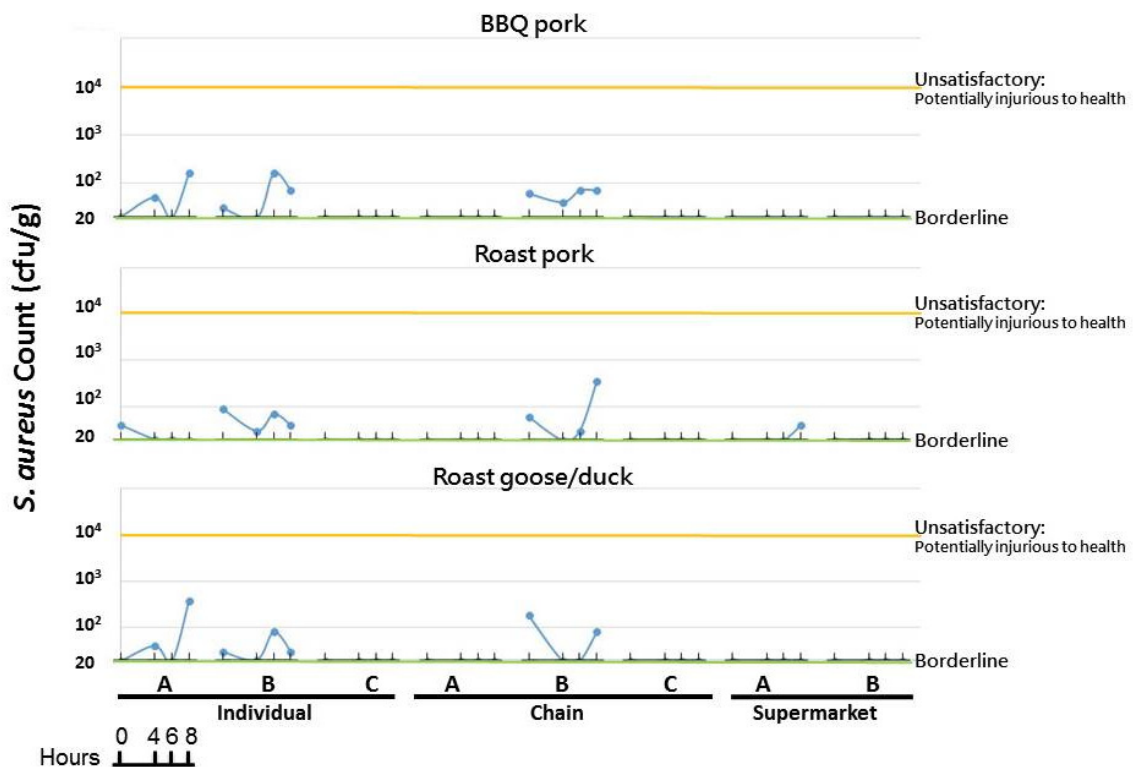
- BBQ pork was 44 cfu/g (ranging from 10 cfu/g to 160 cfu/g);
- roast pork was 60 cfu/g (ranging from 10 cfu/g to 350 cfu/g); and
- roast goose/duck was 66 cfu/g (ranging from 10 cfu/g to 370 cfu/g),

assuming that those reported with *S. aureus* < 20 cfu/g contained 10 cfu/g, the detection limit of the test. It was also noted that at the end of the eight-hour display, *S. aureus* counts in these samples were much lower than 10^4 cfu/g, a level considered potentially injurious to health (Figure 3).

36. In this study, *S. aureus* was not detected in all “chopped samples” of roast meats taken from supermarkets A and B at the start of display and during the following six hours. Only a relatively low level (40 cfu/g) of

S. aureus was detected in a sample of roast pork taken from supermarket A after displaying for eight hours.

Figure 3. Change of *S. aureus* counts in roast meats stored under ambient conditions



Remark: The scale above each store/restaurant on X-axis corresponds to the time points 0 hour, 4 hours, 6 hours, and 8 hours. A base-10 log scale is used for the Y-axis. *S. aureus* count > 10⁴ cfu/g is considered “Unsatisfactory:potentially injurious to health and/or unfit for human consumption”. *S. aureus* count ≥ 20 cfu/g and ≤ 10⁴ cfu/g is considered as borderline in terms of microbiological safety. “Individual”: Individual shop/restaurant; “Chain”: Chain store/restaurant; “Supermarket”: Supermarket stall. For samples reported to contain < 20 cfu/g, the assumed *S. aureus* level is 10 cfu/g for plotting the graphs.

Water activity of roast meats

37. The a_w of roast meats measured at the start of display are summarised in Table 4. For the meat portion, BBQ pork samples were found to have the lowest mean a_w of 0.95 (ranging from 0.93 to 0.97), followed by roast pork (mean a_w of 0.97, ranging from 0.94 to 0.99) and

roast goose/duck (mean a_w of 0.98, ranging from 0.98 to 0.99). Regarding the a_w of the skin, the mean a_w values of the skin of roast pork and roast duck/goose were 0.77 (ranging from 0.64 to 0.86) and 0.95 (ranging from 0.91 to 0.97) respectively (Table 4). Table 4 also showed that the a_w values of skins were always lower than that of their corresponding meat portions, and only the mean a_w of the roast pork skin was found below the limits of growth (i.e., 0.83) and toxin production by *S. aureus* (i.e., 0.87).

Table 4. Water activity of roasted products at the start of storage under ambient conditions and comparison with reported values

Roasted products	a_w in this study (n=8) (Mean & s.d.)	Reported a_w in other studies
BBQ pork	Meat - 0.95 ±0.01 (Range: 0.93 to 0.97)	<u>United States</u> ¹⁹ Center slices – Median: 0.95 (Range: 0.89 to 0.97) Trimblings of the surface – Median: 0.93 (Range: 0.88 to 0.97) Diced pieces left at room temperature for a few hours – 0.86
Roast pork	Skin - 0.77 ±0.09 (Range: 0.64 to 0.86) Meat - 0.97 ±0.02 (Range: 0.94 to 0.99)	<u>Canada</u> ⁸ Skin - 0.70 ±0.072 Cavity (Exposed surface) - 0.81 ±0.054
Roast goose/ duck	Skin - 0.95 ±0.02 (Range: 0.91 to 0.97) Meat - 0.98 ±0.01 (Range: 0.98 to 0.99)	<u>United States</u> ¹⁹ Skin - 0.87 to 0.99 Center slice - 0.91 to 0.99

38. The changes in the a_w values of roast meats (meat portions) during the eight-hour storage period at ambient temperature are shown in Figure 4. In general, the BBQ pork samples had lower a_w levels, ranging from 0.93 to 0.98 while the a_w values of roast pork ranged from 0.95 to 0.99 (except for a sample (a_w : 0.90) from the individual shop A) and roast goose/duck meat ranged from 0.97 to 0.99.

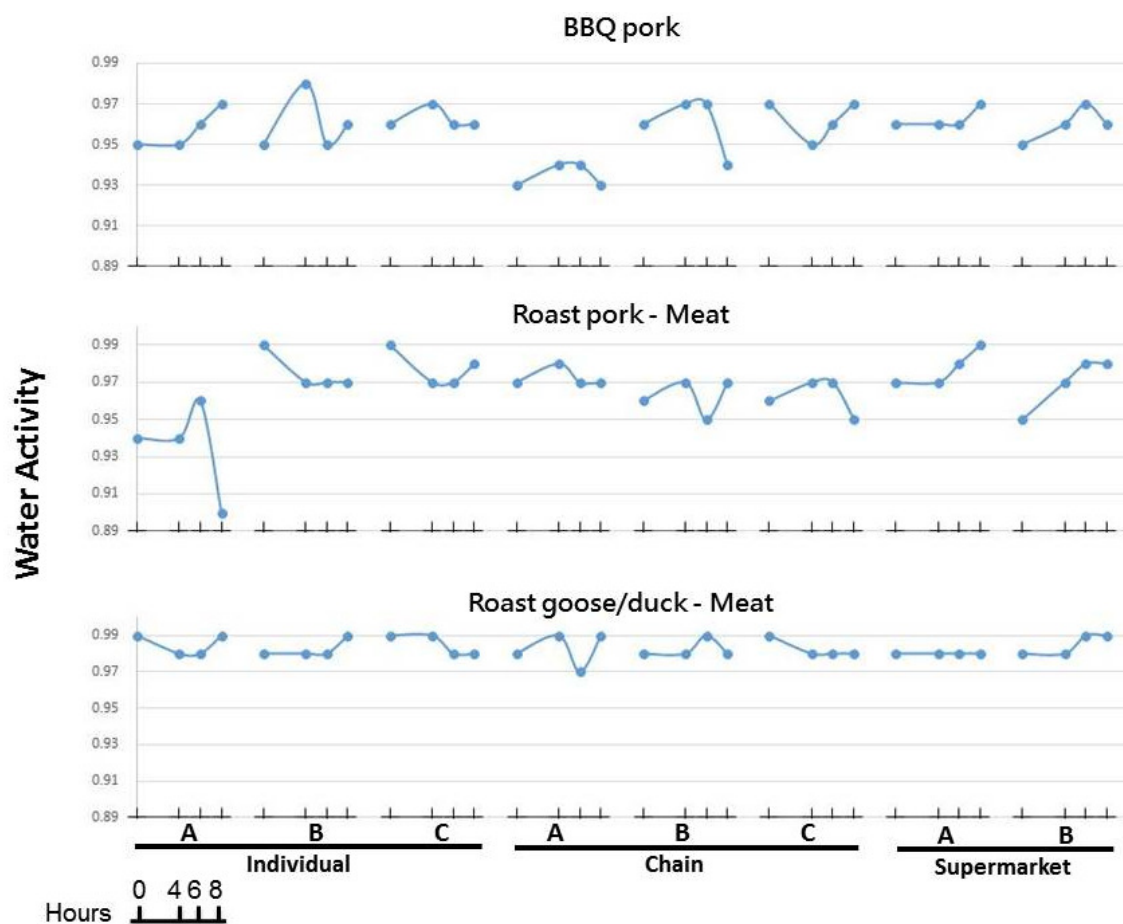
39. Figure 4 showed that the changes of the a_w values of “unchopped samples” (meat portion) during storage were erratic (i.e., no general patterns); and out of 18 “unchopped samples”, there were five samples with the a_w increased, six unchanged and seven decreased after the eight-hour display:-

- for unchopped BBQ pork samples: two samples with the a_w increased, three unchanged and one decreased.
- for unchopped roast pork samples: one sample with the a_w increased, one unchanged, and four decreased.
- for unchopped roast duck/goose samples: two samples with the a_w increased, two unchanged and two decreased.

40. On the contrary, among the six “chopped samples” taken from the two supermarkets, five had the a_w increased (ranging from 0.1 to 0.3) and one unchanged at the end of the eight-hour display.

Figure 4. Change of water activity in roast meats (meat portion) stored

under ambient conditions



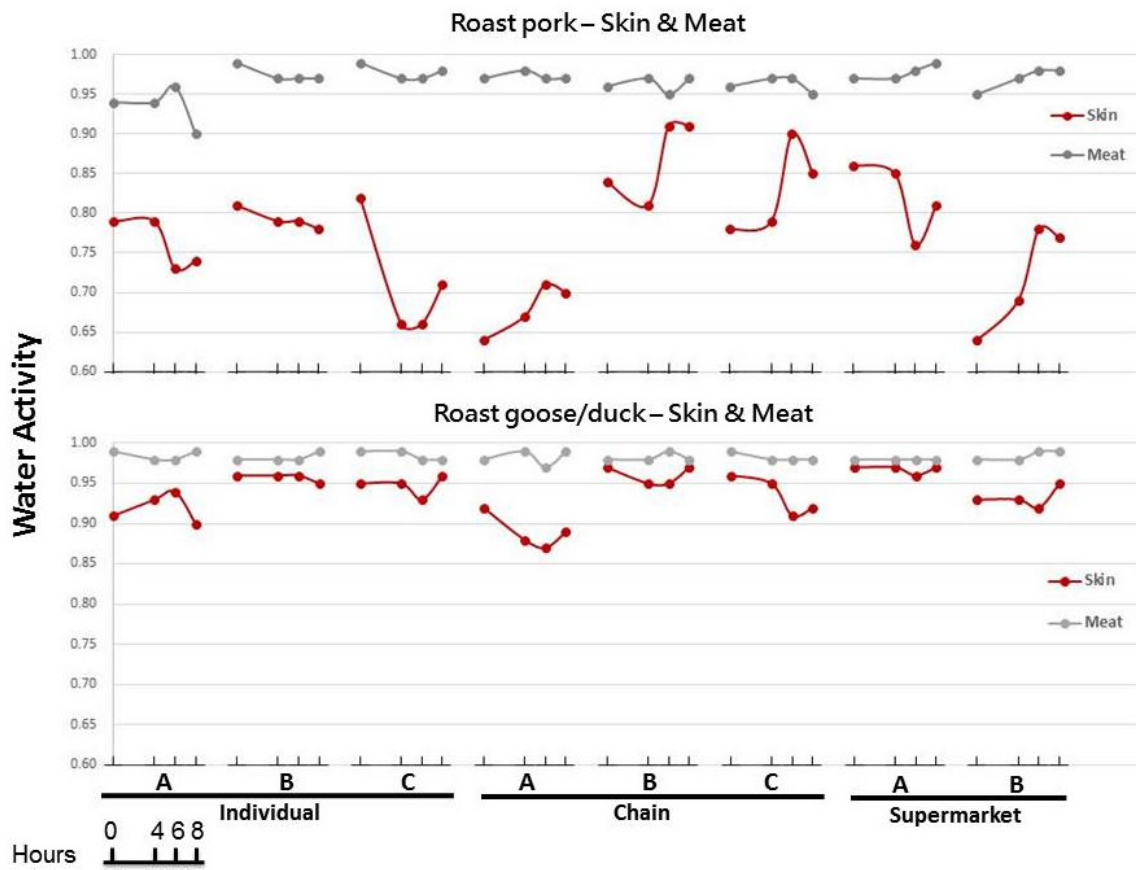
Remark: The scale above each store/restaurant on X-axis corresponds to the time points 0 hour, 4 hours, 6 hours, and 8 hours. “Individual”: Individual shop/restaurant; “Chain”: Chain store/restaurant; “Supermarket”: Supermarket stall.

41. As regards the a_w of the skins of roast pork and roast goose/duck samples, the following observations can be made (Figure 5)

- the a_w of all roast pork skin samples at the start were below 0.87, a level below which toxins cannot be produced by *S. aureus*, and five (out of eight) roast pork skin samples had initial and final a_w below 0.83, a level below which *S. aureus* cannot grow; and
- all roast goose/duck skin samples were found to have the a_w values at or above 0.87 during the storage period.

Figure 5. Change of water activity in roast pork and roast goose/duck

(skin & meat) stored under ambient conditions



Remark: The scale above each store/restaurant on X-axis corresponds to the time points 0 hour, 4 hours, 6 hours, and 8 hours. “Individual”: Individual shop/restaurant; “Chain”: Chain store/restaurant; “Supermarket”: Supermarket stall.

Survey on preparation and handling practices

42. Information on the preparation and handling practices of roast meats by the food businesses was collected and are summarised in Figure 6 and Table 4.

43. Five, among eight, businesses received raw meats, and produced roast meats on their own premises. Two businesses received partially processed meats which were then roasted on-site (Table 4). Partially processed meats (i.e., as intermediate products in Table 4) were meats that have been briefly cooked/processed in other locations and delivered to the

food premises on the same day for further processing such as roasting. One business (i.e., the shop from the supermarket chain B) received fully-cooked meats which were reportedly reheated before selling.

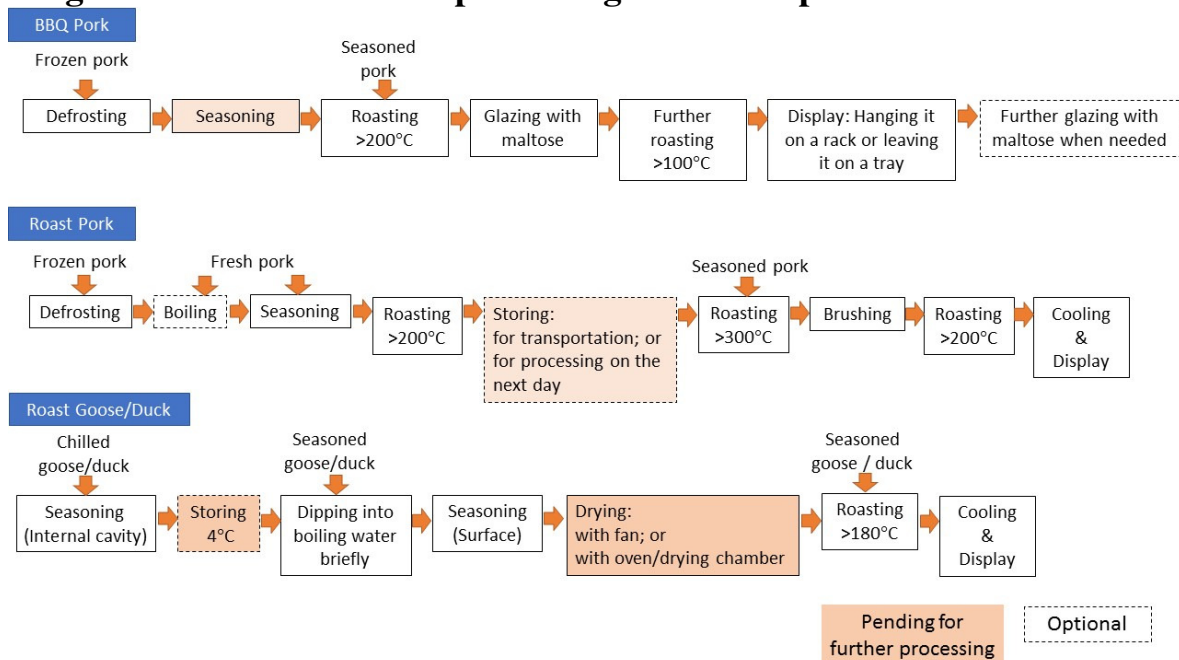
44. Pork for the production of roast pork and BBQ pork could be refrigerated before roasting while goose/duck were, among others, briefly boiled and dried before roasting for the production of a crispy skin. According to the food businesses, drying could be accomplished with a fan under ambient conditions for a period of time (e.g. overnight) or in a drying chamber with a mean for temperature control (Figure 6 and Table 4). It was also reported that roast goose/duck could be dried in an oven to speed up the drying process or when the relative humidity was high.

45. In this study, roast meats were displayed either by hanging on rack (in shops and restaurants) or in cling film-wrapped packages (in supermarkets) (Table 4). As regards the time of displaying roast meats on the rack, some businesses indicated that the roasted products were prepared in several batches (usually two to three batches) through the day, and the last batch was displayed until the end of the business day. In general, owing to the quick product turnover, the roast products were reportedly displayed for less than two to four hours. As for cling film-wrapped roast meats, it was reported that they were displayed for less than two to six hours, usually with time records (Table 4) and uncut roast meats would be kept/displayed for an unspecified period of time.

46. In order to understand how the roast meats were handled during display at ambient temperature, some hygienic practices of the food businesses were asked (Table 4). Wearing gloves appeared not a common practice among the participating food businesses; only two out of eight businesses required their food handlers to wear gloves when handling roast

meats. Functional hand-washing facilities were present around the areas for chopping roast meats. In general, chopping boards were cleaned by scratching with chopping knives and washed with hot water by the end of business day. Besides, shops from the restaurant and supermarket chains were found more likely to use detergent, disinfectant, or sanitiser to clean and disinfect their chopping boards and knives. (Table 4).

Figure 6. Overview on the processing of roasted products



Remark: Summary based on the information from interviewees.

Table 4. Summary on the handling practices for roasted products

	Individual			Chain			Supermarket	
	A	B	C	A	B	C	A	B
Raw materials for processing								
BBQ Pork	Frozen	Frozen	Frozen	Int. products	Int. products	Frozen	Frozen	Cooked
Roast Pork	Frozen	Chilled pig	Frozen	Int. products	Int. products (pig)	Int. products	Frozen	Cooked
Roast Goose/ Duck	Chilled goose	Chilled duck	Chilled duck	Int. products (goose)	Int. products (duck)	Chilled goose	Chilled duck	Cooked duck
Batches								
BBQ Pork	2	3 - 4	3	2	3	6	3	2
Roast Pork	1	2 – 3	3	2	2	2	3	2
Roast Goose/ Duck	2	3	3	4	2	5	1	2
Drying goose/duck								
First batch	Fan (Overnight)	Fan (Overnight)	Fan/Oven		Fan (Overnight)	Drying chamber (Overnight)	Fan (Overnight)	
Other batches	Oven	Fan	Fan/Oven			Drying chamber (23 °C)	Fan	
Display								
Hang on rack	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wrapped					Some		Some	Some
Displaying time	End of business	End of business	< 2 h to 4 h	< 2 h	Wrapped:<2 h Hang: 2 to 4 h	2 to 4 h	Wrapped pack:6 h Uncut: longer	Wrapped pack: 6 h Uncut: longer
Gloves								
Gloves	No	No	No	No	No	Yes	No	Yes
Cleaning chopping board								
Scratch with chopping knife	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hot water	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Detergent			Yes					Yes
Disinfectant					Yes		Yes	Yes
Sanitiser					Yes	Yes (labeled for use on chopping board)		Yes (labeled for use on chopping board)

Remark: This table is prepared on the basis of reported information from interviewees. Int. products: Intermediate products

DISCUSSION

Changes of microbiological quality during prolonged storage under ambient conditions

47. In line with the results of several overseas studies, the results of this study reveal that Chinese-style roast meats (i.e., BBQ pork, roasted pork and roast duck/goose) do not support rapid bacterial growth. The results showed that in general the growth of bacteria in the “unchopped samples” was slow. In fact, in many “unchopped samples” (10 out of 18 samples), the number of bacteria either remained the same or decreased. For those “unchopped samples” with bacterial growth detected after the eight-hour display, their ACC were still lower than 10^6 cfu/g, a level above which the samples would be considered unsatisfactory. The “unchopped samples” were those roast meats, taken from the individual retail shops and restaurants, that had been hung and displayed in storefront windows for a certain period of time before being chopped into pieces and sampled. The slow bacterial growth was likely due to the protection provided by scalding, surface drying and roasting in a salty-sugary glaze.^{10,12}

48. On the other hand, the bacterial growth in the “chopped samples” was found to be faster than that in the “unchopped samples”. Owing to the faster bacterial growth, among the six “chopped samples” taken, the ACC of three became unsatisfactory (i.e., $\geq 10^6$ cfu/g) after displaying for six hours and another two were unsatisfactory after displaying for eight hours. The “chopped samples” were those roast meats, taken from supermarkets, that had been chopped into small pieces and wrapped in cling film at the start of display. The chopping process inevitably contaminated the surfaces of every piece of the roast meats with bacteria

as well as increased the surface area of the meat for bacterial growth during the period of display. Besides, among the six “chopped samples” of meat portions taken, five were found to have a small increase in a_w , which may be one of the reasons accounting for the faster bacterial growth in the “chopped samples”.⁷ The phenomenon of fast bacterial growth in chopped roast meats suggests that roast meats, once being chopped into pieces, should be considered potentially hazardous food, and should observe the ‘two-hour/four-hour rule’ if they are stored at ambient temperature. Hence, chopped roast meats are preferably to be sold within two hours, taking into account further handling at room temperature by consumers after purchase.

49. The Food Standards Australia and New Zealand (FSANZ) also states that the practice of displaying the traditional Chinese roast ducks, chicken and pork at ambient temperature in a shop is generally considered safe because the surfaces of these products do not support rapid bacterial growth.²⁰ However, once the roast meat is chopped, the surface protection is lost and bacteria may grow fast on the product. FSANZ holds the view that chopped roast meat products must be stored under temperature control or must observe the ‘two-hour/four-hour rule’ if they are stored at ambient temperature.²⁰

50. *E. coli* is commonly found in the gut of humans and their presence in food generally indicates potential faecal contamination. The presence of low levels of *E. coli* in most samples especially at the start of display suggests that in general, food handlers of the participating businesses practised satisfactory hand hygiene during the handling of roast meats.

Contamination by *S. aureus*

51. In a review of local staphylococcal food poisoning in Hong Kong in 2011, the commonest associated food items were ready-to-eat foods, including chicken and siu-mei, purchased from food premises.⁴ Poor hygiene of the food handlers was often identified as one of the contributing factors in causing the outbreaks. Previous local studies also reported that there could be around 20% food handlers carrying *S. aureus* and around half of the roast meats were found to have contaminated with *S. aureus*.^{21,22,23}

52. In this study, *S. aureus* was detected in all three types of “unchopped samples” taken from two individual shops and one chain shop during the eight-hour period of time. However, the growth of *S. aureus* was slow in all these “unchopped samples” (i.e., ranging from a 0.3-fold increase to a 37-fold increase), and at the end of the eight-hour display, *S. aureus* counts in these samples were much lower than the level considered potentially injurious to health (i.e., $<10^4$ cfu/g). The slow growth of *S. aureus* in these “unchopped samples” suggests that when not chopped into pieces, roast meats do not provide a favourable environment for the growth of bacteria including *S. aureus*.

53. It is worth noting that the rate of growth of *S. aureus* in the “chopped samples” could not be determined because *S. aureus* was not detected in all “chopped samples” collected from the two supermarkets at the start of display as well as during the first six-hour of display. Nonetheless, taking the rapid growth of ACC in the “chopped samples” into consideration, it is reasonable to believe that if chopped roast meats are contaminated with *S. aureus* by food handlers after roasting, *S. aureus*

may be able to grow quickly to a level that may become a public health concern.

54. In general, regarding the prevention of the contamination of roast meats with *S. aureus*, the chain shops (i.e., from the store/restaurants and supermarket chains) seemed to have a better performance than that of the individual shops. It was noted that chain shops, in general, had working guidelines/instructions (e.g. on food preparation, storage, hygiene practices, colour codes of equipment, cleaning schedule, etc.) for staff members to follow. One chain shop had refrigerator temperature monitoring records and sale records displaying in the food processing area. These measures may serve to remind food handlers to observe good hygienic practices (GHPs), reducing the chance of contaminating roast meats with *S. aureus*. Hence, the implementation of better food safety management systems and tighter hygiene measures of the chain shops may be the reason accounting for the lower prevalence of *S. aureus* in their roast meat.

Change in water activity during storage under ambient conditions

55. The a_w is one of the factors which can affect the growth of bacteria. Most food has an a_w greater than 0.95 which supports the growth of bacteria, yeast and mould. Water activity can be decreased by physically removing water (e.g. drying), by adding solutes such as salt or sugar, by freezing or a combination of these methods.

56. Staphylococcal food poisoning is caused by the ingestion of pre-formed enterotoxins in food, in which *S. aureus* produces toxins over a range of a_w from 0.87 to >0.99, and optimally at an a_w of 0.98.^{6,24} In this study, five (out of eight) roast pork skin samples had initial and final a_w

below 0.83, a level below which *S. aureus* cannot grow. Hence, the low a_w of roast pork skin may provide certain levels of protection in reducing the risk of *S. aureus* poisoning. Overseas studies also showed that the a_w of the skin and cavity (i.e., inside surface, which was not measured in this study) of roast pork were both below 0.85, indicating that the surfaces can limit pathogen growth at ambient temperature.⁸

57. In general, the a_w levels of BBQ pork as well as the meat portions of roast pork and roast duck/goose measured during the whole eight-hour period of display were not low enough to inhibit the growth of *S. aureus* as well as toxin production on these meats. In view of the fact that the rates of growth of *S. aureus* on these meats were slower than expected, there should be other factors retarding the growth of *S. aureus*. For example, seasoning for roast pork skin and roast goose/duck skin usually contained vinegar which could reduce the pH and help to retard the growth of *S. aureus* and toxin production in combination with lower a_w values.

58. As mentioned before, there seemed to exist a general trend of slight increase in the a_w of the samples wrapped in cling film after eight-hour of display. The increase in the a_w may be one of the reasons that bacteria growth was faster in the “chopped samples”.

Hygienic practice of processing, display and cleaning

59. In this study, most participating businesses produced roasted meats in several batches a day which effectively reduced the time of displaying the roast meats at ambient temperature. This is particularly important to shops offering chopped and wrapped roast meats because once chopped into small pieces, bacterial could grow fast in these cut meats. Where necessary, a mechanism should be in place (e.g. marking or colour-

coding) for batch identification, avoiding unnecessary prolonged display of roast meats originating from earlier batches.

60. Food businesses selling chopped roast meats in package forms may include a consumer advisory on placards or labels of the products, reminding consumers that chopped roast meat should be consumed as soon as possible.

61. *S. aureus* is commonly carried on the skin or in the nasal cavity of healthy people. In this study, food handlers of most participating food businesses also handled raw meat during the production of roast meats (Table 4), and therefore, they might be contaminated with *S. aureus*, including the strains of both human and animal origin.²⁵ Some food handlers in this study wore gloves during handling of roast meats, and it happened that the samples collected from the shops of these food handlers were not contaminated with *S. aureus*. However, gloves have to be changed when soiled as gloves can be a source of contamination just as bare hands can. Furthermore, as some food handlers may be nasal carriers of *S. aureus*, food handlers should wear face masks as far as possible, especially when handling ready-to-eat roast meats. In short, food handlers should observe the GHPs in order to prevent roast meats from being contaminated with pathogenic microbes such as *S. aureus*.

62. Apart from food handlers, food contact surfaces are another source of contamination. Among different types of food contact surfaces, chopping boards are directly in contact with roast meats, and chopping boards with deep gouges and cuts may increase the risk of cross-contamination from bacteria hidden in these marks.²⁶ Hot water was reportedly commonly used by the participating businesses to clean and

disinfect the surfaces of chopping boards. Besides hot water, shops from chains also used detergents, disinfectants and/or sanitisers to clean chopping boards (Table 4).

Limitations

63. In this study, samples from only eight shops were taken, and challenge tests were not conducted to determine the end points of safety due to resource limitation.

64. In some samples, the presence as well as the growth of bacteria were quite variable. This may be due to the fact that there may be cross-contamination of roast meats from food handlers and the environment during the cooling period before the first samples was taken. Besides, in the real-life situation, the environmental conditions of the participating food businesses (e.g. the ambient temperature) were different and the contamination was likely unpredictable. Unlike a challenge test under a set of well-controlled laboratory conditions where a pre-defined number of bacteria is inoculated evenly onto the food surface, in this study, bacteria were likely unevenly distributed in the environment, rendering the contamination of roast meats with bacteria unpredictable, and introducing uncertainties to the patterns of bacterial growth in subsequent samples.

CONCLUSION AND RECOMMENDATIONS

65. The results of this study show that roast meats, before being chopped, do not favour rapid bacterial growth. Hence, the current practice of hanging and displaying whole pieces of roast meats in storefront windows of siu-mei shops and restaurants for a period of time without

temperature control is unlikely to pose a public health risk. The businesses in this study usually prepared their products in several batches (i.e., two to three batches) through the day, and because of the quick product turnover, most of the businesses could sell their products within two or four hours.

66. Some participating food businesses provided roast meats in precut and packaged forms. That is, food handlers chopped the freshly prepared roast meats into pieces, wrapped them in cling film and displayed them for a variable period of time before being purchased by consumers. This study showed that bacteria could grow fast once roast meats were chopped into pieces. Therefore, chopped roast meats should be sold within four hours, preferably within two hours after chopping.

67. Consumers should note that once a displaying roast meat is chopped into pieces by the food handler of a siu-mei shop, the chopped roast meat should be consumed within four hours.

68. Although the presence of low levels of *S. aureus* in some roast meat samples indicates no safety concern, there is still room for improvement for food handlers handling roast meats. Food handlers should be particularly aware that, besides hands, the carriage of *S. aureus* in other body parts, e.g. mouth and nose, can be a source of contamination and it is important to maintain a high standard of personal hygiene and cleanliness (such as frequent and thorough washing of hands and/or wearing gloves and masks) in order to prevent *S. aureus* that may be present on hands from transferring to the roast meats.

Advice to Public

- Check whether the premises have a FEHD licence and have the licence/endorsement for the sale of siu-mei.
- Chopped roast meats (e.g. in package forms) that have already been displayed on a food display counter should be consumed as soon as possible. For consumption at a later time, keep the package under refrigeration as soon as possible and reheat the roast meats thoroughly before consumption.
- Roast meat which are chopped at the moment of purchase should be consumed within four hours after purchase.
- Separate raw food, especially raw meat, poultry and seafood, from roast meats in your shopping trolley or basket.

Advice to Trade

69. The CFS has updated the trade guidelines on “Food Safety Advice for Producing Siu-mei”. Among others, relevant GHPs have been incorporated into the guidelines, aiming at preventing cross contamination of siu-mei during production, and growth of bacteria during display/storage. The gist of the guidelines is summarised below:

Production

Schedule —

- Well plan the production schedule to avoid too early production before sale and prolonged storage of roasted products at room temperature. Preferably adopt two rounds of roasting – one morning session and one afternoon session – to cater for the demand during lunch and dinner hours.

Quantity —

- Well estimate the quantity required to avoid over-production. [similar to Schedule]

Defrosting —

- Thaw frozen meat with correct methods, i.e.,
 - place under refrigeration with temperature at 4°C or below; or
 - place under cool running water
- Do not thaw frozen food under room temperature.

Removing charred areas (for roast pork) —

- Use knife to scrape charred areas off roast pork instead of metal wire brushes, in order to eliminate the physical hazard of broken wire fragments trapped inside the meat.

Drying (for roast duck/goose/chicken) —

- If drying in open area, conduct the drying process for no longer than six hours in a well-ventilated area, separated from the area for cooked or ready-to-eat food. Check that the core temperature of the duck/goose/chicken does not reach more than 25°C throughout the drying process.
- If weather condition is not optimal for drying process, e.g. over 25°C or humid condition, conduct drying process for a shorter period of time in an oven instead.

Post-roasting handling

Cooling and packing —

- Designate a clean area, away from raw food, for cooling and packing of the roasted products.
- Properly sanitise all containers for holding roasted products before use.
- Provide proper covers for the containers.
- Properly clean hands before direct contact with roasted products.
- Use gloves when necessary

Transportation —

- Use clean vehicle to reduce the risk of cross-contamination.
- Ensure that the vehicle is not used at the same time for transportation of raw food or chemicals.
- Cover the roasted products while leaving room to avoid moisture build-up.
- Shorten the delivery time as far as practicable to prevent prolonged storage of roasted products at room temperature.
- Carry the meats with a hanging hook or BBQ pilers to minimise direct contact of the roasted products by hands, or take all such steps as may be reasonably necessary to protect the food from risk of contamination or deterioration.

Display for sale

Storage —

- At the retail outlets, store and display roasted products in insect-proof and dust-proof showcases. Do not store raw food inside the same showcases.

- Ensure there is enough space in the display area or storage area to avoid stacking of meats.
- Carry the meats using a hanging hook or BBQ pliers to minimise direct contact of roasted products by hands, or take all such steps as may be reasonably necessary to protect the food from risk of contamination or deterioration.
- Well estimate the demand for sale, do not order excessively.
- Cut roasted products that have been displayed at room temperature:
 - for less than two hours, they can be refrigerated for final use later or used before the four hours limit is up.
 - for more than two hours but less than four hours, they should be used before the four hours limit is up but should not be returned to the refrigerator.
 - for more than four hours, they should be discarded.

Hence, chopped roast meats are preferably to be sold within two hours, taking into account further handling at room temperature by consumers after purchase.

Cutting and packaging —

- Maintain good personal hygiene
 - Wear clean overalls.
 - Wear a face mask during food handling. Discard the mask when damaged, soiled or after prolonged use.
 - Discard disposable gloves when damaged, soiled, or during breaks. Wash hands between glove change and after removal of gloves.
 - Before handling foods, after using toilets or touching unclean materials (e.g. after disposing of rubbish, after handling cash), wash hands thoroughly. Rub hands with liquid soap for at least

20 seconds.

- Observe appropriate hand washing method.
(http://www.cfs.gov.hk/english/multimedia/multimedia_pub/files/food_handlers.pdf)
- Properly cover the open wounds and wear gloves.
(http://www.cfs.gov.hk/english/multimedia/multimedia_pub/files/How_to_use_gloves_for_food_handlers.pdf)
- Suspend from engaging in any food handling work when you are suffering or suspected to be suffering from an infectious disease or symptoms of illness such as flu, diarrhoea, vomiting, jaundice, fever, sore throat and abdominal pain. Wear a surgical mask if you have respiratory symptoms. Seek medical advice promptly.

Equipment —

- Hand washing and drying facilities should be suitably located in food preparation or production areas to ensure food handlers have ready access to them. Hand washing facilities should be supplied with hand cleanser (soap). Where possible, hand washing facilities should have non-hand operable taps and single-use towels to help preventing the re-contamination of clean hands.
- Use separate utensils and equipment to handle raw food and cooked food respectively.
- Regularly sanitise the utensils (including cutting boards and knives), equipment, working tables and wiping cloths with boiling water (or hot water $\geq 77^{\circ}\text{C}$) or sanitiser.
- Follow the instruction of manufactures of sanitiser or disinfectants for effective sanitation, e.g. contact time, correct concentration, and shelf life after dilution, etc.

- The chemicals used for sanitation, appropriately of food grade, should be suitable for use with food contact surfaces and eating utensils.
- For sanitation, alternatives such as vinegar, lemon juice and methylated spirits are not generally recommended unless specific methodology (including concentration, pH, temperature, contact time, etc.) has been validated and verified to be effective.
- Use cutting boards in good condition. Discard those with cracks.

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