# A NOVEL CABINET FOR THE HOT WATER DECONTAMINATION OF SIDES OF BEEF

K.R. Davey, CSIRO, Division of Food Processing, Meat Research Laboratory, P.O. Box 12, Cannon Hill, Queensland 4170, Australia

## SUMMARY

A beef decontamination cabinet, based on a novel hot water distributor design, is described and a laboratory evaluation of it is reported. The cabinet uses low pressure distribution of hot water in contrast to more conventional pressure spraying and resulted from a mathematical analysis of the operation. The cabinet does not have doors. Laboratory determined data for microbial reductions at the meat surface together with concomitant heat and evaporative losses from the cabinet are presented and summarised in a series of equations to define cabinet operation. This investigation provides more comprehensive results than previous research in decontamination. Running cost using the novel cabinet was one-third that of an existing spray cabinet when compared at the maximum reduction of $\log_{10}1.3$ (95%) achieved by the spray cabinet. An overall mean maximum reduction of *c.* log 3 (99.9%) was obtained with the novel cabinet without permanent damage to meat bloom.

## INTRODUCTION

Decontamination may become important to Australia, the world's largest exporter of meat. The problem of contamination arises subsequent to slaughter when microorganisms from the gastro-intestinal tract and exterior (hide) of the animal can be transferred to the surface tissue of the dressed carcass. The presence of such contaminants, especially salmonellas, are a potential hazard to human health. Contamination is not uniquely an Australian problem.

There have been a number of investigations into decontamination using hot water. Hot water has a number of advantages including: reliable reductions of bacterial numbers; removal of lose dirt, does not itself contaminate meat; is generally available. Hot water decontamination is therefore likely to be readily accepted. The effectiveness of hot water applied with high pressure spraying to reduce numbers of contaminants with and without the addition of chlorine has been widely investigated (Graham et al. 1978; Cain and Powell 1983; Kotula et al. 1974; Kelly et al. 1981). Data from these studies however are highly variable and direct comparison is difficult due partly to a lack of a systematic study of the process. Reductions in contaminants and concomitant heat losses and costs will depend on several factors including: the method of transferring water to the carcass; water temperature; the rate of processing of the sides; ambient temperature.

A mathematical model was constructed to explore theoretically the effects of changes in these and other process variables and to evaluate design changes. In this paper two methods of applying the water in a cabinet designed for continuous and on-line decontamination are compared. These are: conventional pressure sprays and an alternative distributor, or waterfall, method. Details of the resulting realisation and testing of a practical distributor cabinet and its better performance are presented.

## EXPERIMENTAL METHODS

A convenient geometry for a decontamination cabinet is a construction that simply fits over existing conveyor systems without impeding the continuous processing of sides.

Conventional pressure spraying of hot water is done using vertical banks of nozzles. A disadvantage with pressure spraying is that water will spray the opposite walls of the cabinet past the contours of the beef sides. The cabinet walls will therefore be at the water temperature. To limit heat losses the walls will have to be thermally insulated. Other disadvantages with pressure spraying are: the need for high pressures and associated pumping costs, and; the possibility of spray jets blocking. However the principal drawback is that in spraying the surface area of the water is greatly increased because of the many individual droplets and therefore heat losses are greater. There will be a large temperature gradient from the jet outlets to the beef sides. The fine droplets resulting from the use of sprays may also cause excessive evaporation or "misting" which condenses on exposed surfaces in the work area.

Alternatively, if the water is poured and distributed onto the sides of beef the surface area of the water for heat loss is greatly reduced, and, for a given supply water temperature, greater reductions of bacterial contaminants could be expected. Further there is not the need for insulation of the cabinet walls and misting should be reduced.

With either method there will be, after some time of operation of the cabinet, a steady-state heat transfer from the hot water to the surface of the sides and to the air inside the cabinet. Evaporation from the hot water to the cabinet air will create a density driving force for air interchange between warm air in the cabinet and cool air outside, aided by the moving sides.

### *Model development*

Initial model analyses showed that cabinet doors would not help to reduce running cost and were not considered further (Davey 1988). Microbial data were produced at bench-scale by pouring hot water over samples of meat inoculated with *Escherichia coli* by Smith and Graham (1978) and Smith (1988). *E.coli* was used as this microorganism is non-pathogenic and behaves thermally very similarly to salmonellas. Conclusions available from *E.coli* studies should therefore be applicable to salmonellas. The inactivation kinetics of this bench data were modelled (Davey 1988) using a 1st order equation with an Arrhenius temperature dependence - this is widely used to model kinetics.

Using a computer model based on these kinetic data together with published correlations for air movement and evaporative losses (Davey 1988), it was possible to prepare a summary of the two methods of spray (SPRAY) and distributor (DIST). For a given reduction of $\log_{10}1.45$ and a given inlet water temperature of 80°C, the SPRAY cabinet required a greater predicted exposure time, and therefore longer cabinet, with greater

**TABLE 1:** Comparison of predictions for idealised DIST and SPRAY cabinets for $\log_{10}1.45$ reduction in E.coli (Davey 1988)

| Predicted value | Cabinet | |
|---|---|---|
| | DIST | SPRAY |
| Length (m) | 0.87 | 1.05 |
| Heat losses (kJ/s) | 18.3 | 71.2 |

heat losses and running cost (Table 1). Predictions also revealed that the heat losses from the DIST cabinet would be largely unaffected by increasing the flow rate of water because the water film thickness on the meat does not alter the surface area for evaporative losses very much. By contrast, increased flow rates with SPRAY result in greater number of droplets of water and therefore ever increasing heat losses and associated costs.

A potential drawback with the DIST cabinet however is the difficulty of obtaining an adequate coverage of the irregular shaped sides with hot water - something achieved relatively easily with SPRAY - nevertheless it was decided from the model study to experimentally investigate a full-scale DIST cabinet.

### *The distributor cabinet*

A distributor was designed to fit as simply as possible over an existing dressing conveyor. To help assess the coverage of the sides of beef with water, the contents of cans of shaving cream were painted onto the sides using a painters brush. The emulsion remained stable for about 50 min and, importantly, any emulsion not washed directly from the surface meat as the side passed through the cabinet remained in place. The areas not covered by the water were therefore obvious. The location and dimensions of the DIST cabinet, its weirs and baffles to distribute water were fixed from these empirical studies. Colour photographs showed good contrast between the red of the lean and yellow of the fat and the remaining white shaving cream. This exercise was repeated and the cabinet gradually modified to the end result shown in Fig.1 (Davey and Smith 1988). The cabinet consists of a recirculation tank, pump, distributor and three baffles and a heater. The distributor contained two internal boxed sections to produce four weirs. The flow rate of water over each weir was adjustable by individual guides that were attached to the top of the boxed sections. The minimum restriction to flow was 30 mm - so that there was little likelihood of blocking.

The water wall was 0.88 m long in the direction of side travel and gave exposure times of *c.* 10 to 20 s at usual conveyor speeds. The minimum necessary water flow to the cabinet for adequate coverage was found experimentally to be 3.2 l/s/m of weir (or a total flow of 11.6 l/s). The sides are required to enter the cabinet with the medial surfaces facing the first baffle. The entire area of the hocks and neck of both the lateral and medial surfaces were covered - sites usually of high contamination - and about 65% of the area of the abdominal and thoracic cavities - sites of low risk. This was considered satisfactory.

Six sites for microbiological testing were selected. These were: lateral surfaces of neck, thoracic cavity, rump, mid back, brisket, and shoulder. The sides were weighed and inoculated following slaughter and dressing with a suspension of *E.coli* (to give a surface count of *c.* $10^{6.8}$ organisms/cm$^2$). They were left to "dry" for about 15 min before tissue was aseptically excised using a sharp cork borer from four random locations within each site area. The sample tissue was blended in sterile water with added peptone before plating. Water temperatures in the recirculation tank and distributor; and temperatures in the cabinet and of the surroundings; were recorded continuously at 0.1 s intervals. Ambient wet-bulb temperatures were recorded also. The sides were pulled through the cabinet using a bollard coupled to a variable speed electric motor to give accurate exposure times of 10 or 20 s. Water temperatures used were *c.* 45, 65, 75 and 85°C (Davey and Smith 1988).

Immediately following exposure, surface tissue was again sampled at each of the test sites and then again following 24 h and 48 h chilling with air temperatures *c.* zero °C.

## RESULTS

There was a pronounced "greying" and "bleaching" of the surface tissue immediately following exposure. Tissue colour reappeared after about 10 to 12 min at ambient (*c.* 14 to 22°C). Bloom was subjectively assessed by a

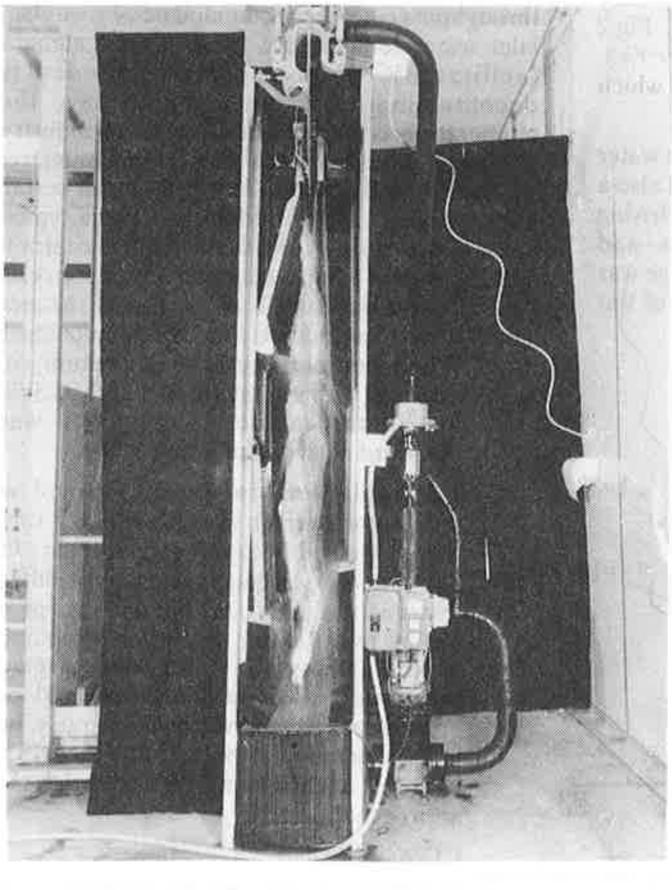

Fig.1 Photograph of the distributor cabinet (showing three baffles and water distribution and orientation of a side of beef).

panel of four laboratory officers - not including the author - at 24 h and 48 h chilling. Sides from animals slaughtered at about the same time but which were not decontaminated were used as controls. Bloom was concluded not to have been permanently and adversely affected even at the higher water temperatures of *c.* 85°C. In a deliberate attempt to impair bloom a side was exposed at 85°C for 32 s. The most obvious effects were permanent browning of tissue in the upper thoracic cavity and on the brisket.

Figure 2 summarises the reductions obtained. The temperature, $T_f$, is the mean water temperature at the surface tissue of the meat. $T_f$ cannot be measured directly but is calculated from a knowledge of temperature distributions and supply water temperature and flow rate (Davey and Smith 1988). Its use permits direct comparisons of different cabinets and a reduction equation to be derived. Each data point is the mean from two sides. An analysis of variance was used to determine the effects of temperature, exposure time and site and time of sampling. Because there was no significant difference between mean reductions at the different sampling times the data were lumped to give a grand mean. Chilling therefore did not further affect the microorganisms.

The linear relationship shown between $T_f$ and reductions was significant ($P < 0.05$) for the two exposure times. That there was no appreciable reduction at *c.* $T_f$ = 45°C - not much above the optimum growth temperature for the microorganism - indicates that reductions are mainly due to thermal injury and not a physical "wash off". Fig.2 can be used to determine reductions of *c.* log 3 (99.9%). Greater reductions will involve exposure times at which bloom will be permanently damaged.

There was a linear relationship ($r = 0.89$) between water vapour pressure driving force and heat losses, and also a linear relationship ($r = 0.92$) between the density driving force for air interchange - aided by the moving sides - and heat losses. Volumetric flow rate of air interchange was *c.* 0.58 $m^3/s$, corresponding to a volume change of the cabinet air every 5.3 s.

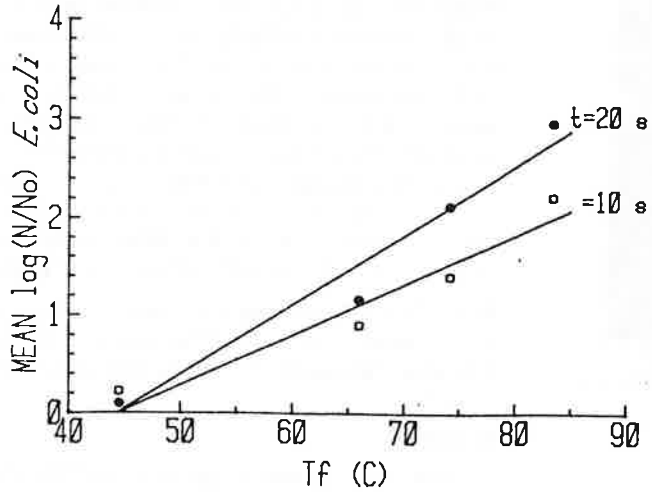

Fig.2 Overall mean $\log_{10}$ reduction of E.coli on sides of beef obtained in the distributor cabinet at four values of $T_f$ (95% confidence limits on two replicates were within 0.35).

Further analysis of the microorganism reduction data showed that there was a significant difference ($P < 0.001$) between reductions at each test site. Least reductions were on the neck. This is due logically to the fact that water exiting the neck will be coolest, but also, probably because of the highly folded nature of the tissue with its many crevices compared for example with the smooth tissue of the cavities. A reduction equation was regressed for each of the six separate sites and overall (Davey and Smith 1988).

There were no difficulties associated with misting, even at the higher temperatures although this might occur at very high ambient humidities.

## DISCUSSION

The experimentally determined data were used to improve the accuracy of the predictions of the model. Using the improved computer model it was possible to trial different reductions and ambient temperatures. Calculations were first carried out for the neck then for each of the other sites. This was used to show that changes in ambient temperature did not appreciably affect heat losses without recourse to further experimental studies.

Whilst a number of different combinations of cabinet length, water temperature and exposure time is possible to obtain a desired reduction, it is recommended that a "standard" cabinet be adopted. This would be based on the laboratory cabinet with a distributor 0.88 m long and a cabinet width of 0.52 m. In this way different throughputs could be accommodated by varying only the inlet water temperature (and cabinet manufacture is facilitated). It is also recommended that the decontamination cabinet should have the water temperature control set to achieve an industry agreed minimum reduction at the point of minimum treatment - which will be the neck. This will almost certainly be a minimum log 1 (90%) reduction. For a typical export abattoir processing 135 sides/h at 1.2 m centre to centre spacing cost for a log 1 reduction is between A$0.015 and A$0.03 - or about 0.016% of the cost of the meat of the side if it were considered low cost manufacturing meat. When compared at the maximum reduction achieved with a spray cabinet of log 1.3 (95%) the distributor cabinet running cost was about one-third (Davey and Smith 1988).

The reductions in *E.coli* obtained with the distributor cabinet were less (*c.* 0.7 times) than those obtained by Smith and Graham (1978) and Smith (1988), largely because of a difference of dynamic similarity and the wide range of tissue texture over a whole side when compared to cuts of meat (Davey and Smith 1988). Predictions of the model based on bench-data and published correlations were nevertheless, largely, borne out in the experimental evaluation of the DIST cabinet thereby highlighting the usefulness of this approach.

## CONCLUSIONS

A DIST cabinet can be used to successfully decontaminate sides of beef. Advantages of the DIST cabinet include its logical simplicity and that it does not impede usual chain throughput permitting a continuous flow of sides. A "standard" cabinet can be used to accommodate a wide range of processing rates by adjusting only the inlet water temperature to the distributor. This facilitates manufacture.

Comparison with an existing SPRAY cabinet confirmed that greater reductions can be obtained with the DIST cabinet, and; that it is about 3 times more cost effective in achieving reductions and with lower capital costs.

The experimentally derived data expressed in model form gives a good basis for a more systematic understanding of the process. This permits changes in a range of process conditions to be assessed.

## ACKNOWLEDGEMENT

The author is grateful to the Australian Meat and Live-stock Research and Development Corporation for financial support.

## REFERENCES

Cain, B.P. and Powell, V.H. (1983). Meat Research Report 3/83, Meat Res. Lab., CSIRO Division of Food Research.

Davey, K.R. (1987). Meat Research Report A/87, Meat Res. Lab., CSIRO Division of Food Research.

Davey, K.R. (1988). *International Journal of Food Science and Technology* - in review.

Davey, K.R. and Smith, M.G. (1988). *International Journal of Food Science and Technology* - in review.

Graham, A., Cain, B.P. and Eustace, I.J. (1978). Meat Research Report 11/78. Meat Res. Lab., CSIRO Division of Food Research.

Kelly, C.A., Dempster, J.F. and McLoughlin, A.J. (1981). *Journal of Applied Bacteriology* **51**:415.

Kotula, A.W., Lusby, W.R., Crouse, J.D. and de Vries, B. (1974). *Journal of Animal Science* **39**:674.

Smith, M.G. (1988). Proceedings, 34th International Congress of Meat Science and Technology - in press.

Smith, M.G. and Graham, A. (1978). *Meat Science* **2**:119.