



## The Effect of Water Pressure and Chlorine Concentration on Microbiological Characteristics of Spray Washed Broiler Carcasses

Pissol AD, de Oliveira D, Toniazzo G, Valduga E & Cansian RL

Department of Chemical and Food Engineering, Federal University of Santa Catarina, Florianópolis, SC, Brazil.

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### Corresponding author:

Débora de Oliveira, M.Sc.  
odebora@uricer.edu.br

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### Abstract

The objective of this study was to evaluate the efficiency of water pressure and concentration of dichloromethane after the evisceration system under the fecal decontamination of chicken carcass surfaces with and without apparent contamination. From a total of 322 carcasses, 50% were intentionally added chicken droppings in an area of more than 2 cm<sup>2</sup> and the rest of carcasses were kept without fecal inoculation. *Escherichia coli* and *Enterobacteriaceae* counting was carried out in samples immediately after the inoculation (initial counting) and after different treatments. Treatments consisted of water with different pressures (1.5, 3.5 and 5.5 Kgf/cm<sup>2</sup>), and the addition of a technological adjuvant (dichloride) at the concentrations of 0, 5 and 10 ppm. The results were validated using 40 chicken carcasses for each treatment by means of a 2<sup>2</sup> factorial statistical design. The results showed no significant differences ( $P < 0.05$ ) between the carcasses with and without initial apparent fecal contamination after passing through the washing nozzles, related to the *E. coli* and *Enterobacteriaceae* countings and the visual characteristics (32 judges) of the products. The binomial pressure-adjuvant concentration influenced the result of microbiological analyses of chicken carcasses; the water pressure demonstrated higher influence compared to the adjuvant concentration. Most of the treatments showed satisfactory results on the fecal decontamination.

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## Introduction

The physio-chemical and hygienic-sanitary quality of meat products depends on the measures which should be obeyed since the pre-slaughter until the consumption moment. After the slaughter and evisceration, some chicken carcasses keep their microbiological characteristics unchanged (Andersen, 1995). However, when the animals are slaughtered, microorganisms from the medium, viscera, soil, water and ration can contaminate the external surface of the meat (Ercoline *et al.*, 2006). Tompkin *et al.* (2001) described that the superficial microbiota of the carcasses freshly slaughtered are from  $10^2$  to  $10^3$  CFU/cm<sup>2</sup>, being found preferentially mesophilic bacteria from the external surface (skin) and the gastrointestinal portion of the animals.

The contamination of the chicken carcasses has important implications for the security and shelf life of the product (Ordóñez-Pereda *et al.*, 2005). Procedures to control the survival and growth of bacteria in the surface are of interest both of industries and regulatory agencies (Dickson and Anderson, 1992).

Recently, in Brazil, the legislation authorized the employment of a washing system in the process of slaughter of chickens to remove the contamination resulted from gastrointestinal content present on the internal and external surfaces of carcasses before the step of pre-cooling, as an alternative to the practice of refile (Brasil, 1999). However, most industries use corrective actions by the withdrawal of fecal contamination of the carcasses by cutting (Brasil, 2003a). This critical point of control (CPC) is described as the limit for the absence of gastrointestinal and bile contamination on the carcasses. The carcasses, after evisceration and before the final toilet with shower water, are inspected one by one in the external and internal surfaces. The contaminated carcass portion goes to a dry toilet, with a standard procedure of withdrawal of fecal contamination by cutting using a knife.

Carcass washing before the cooling system is a standard procedure adopted in some countries. In Canada, this toilet is carried out after the shower washing and before the cooling system. The chemical treatments of the carcasses are not permitted in Europe but are approved in the United States of America. The chlorinated water is used in several countries for controlling the growth of bacteria. The chlorine level should not exceed 50 ppm (Bolder, 1997). The regulation does not prohibit the chemical decontamination of animal food, but the approval is linked to the rigorous prescriptions and just can be authorized after the European Food Safety Authority (EFSA) has performed the analysis of risk (Hugas and Tsigarida, 2008). The International Commission on Microbiological Specifications for Foods - ICMSF (1998) cites that in chicken processes, the application of chlorinated water by prolonged exposure in multiple sprinklings during the process permits the microbial reduction.

In Brazil, the legislation (Brasil, 1999) authorizes the inclusion of dichloroisocyanuric acid and its salts of sodium and potassium as an active principle to use in formulations of products for the disinfection of water for human

consumption. Chlorides derivatives of the organic source, mainly sodium dichloroisocyanate, are being used in industries for the disinfection of water, equipments, packages, due to the easiness of handling, measurement, transport and storage; higher solubility and shelf life; more precise dosage; lower chemical risk (corrosivity) and probability of formation of by-products (Oyarzabal, 2007). While sodium hypochlorite presents a content of active material of approximately 12%, dichloroisocyanuric acid has a content of about 65% (Oyarzabal, 2007).

However, washing of carcasses having fecal contamination using douche, with or without the addition of technological adjuvant, is not a well consolidated practice, requiring more information with respect to the pressure of the sprinklers and the concentration of adjuvant under the microbiological and sensory quality of the product. Based on these aspects, the objective of the present study was to evaluate the efficiency of washing system using douche, after the evisceration line, under the fecal decontamination (*E. coli* and *Enterobacteriaceae*) and the visual aspect, on the chicken carcasse surfaces with and without apparent fecal contamination.

## Materials and Methods

### Design and construction of the slaughterhouse

The samples of chicken carcasses were collected in a slaughterhouse located in the South of Brazil. A total of 322 chicken carcasses were collected, half of the chicken carcasses were added intentionally chicken droppings in a bound area of 2 cm<sup>2</sup> and the rest were kept without fecal inoculations. Samples were analyzed in terms of *Escherichia coli* and *Enterobacteria* counting.

To determine the initial contamination, a total of 22 carcasses were sampled immediately after the contamination and the areas were marked. For this purpose, 25 g of skin and superficial muscle were removed, stored in coded sterile plastic packages and sent to the laboratory for *E. coli* and *Enterobacteria* counting.

The influence of pressure and dichloride concentration on the fecal contamination of carcasses with and without apparent visual contamination was evaluated by a 2<sup>2</sup> factorial experimental design with triplicate of central point (Haalan, 1989). The experiment was carried out in washing douches, located at the end of the evisceration line, before the pre-cooling system. The independent variables of the experimental design and their respective levels are presented in Table 1. The fixed variables were water flow (1.5 L/chicken); water temperature (18°C); rate of passage of carcasses by the washing douche (2.5 seconds); number of sprinklers (24, 12 by each side: 6 directed to the washing of internal region and abdominal opening and 6 directed to the washing of chest and back of carcasses); distance between the sprinklers (205 mm); dimensions of the cabinet (300 cm length, 55 cm wide and 140 cm height); dimensions of the sprinklers (133 cm length, 50 cm wide and 26 cm height from the shower).

The dependent variables were: counting of *E. coli* and *Enterobacteria* of the area

with and without apparent fecal contamination.

The chlorine analysis was carried out by a colorimeter (Merck Spectroquant®, Darmstadt, Germany) and the result was expressed as ppm of free residual chlorine. The pressure was controlled by a manometer (Marval, Porto Alegre, Brazil), expressed as Kgf/cm<sup>2</sup>.

After the analysis of the results of the 2<sup>2</sup> experimental design, validation experiments with a higher number of repetitions were carried out for the experimental conditions that presented better results (5.5 and 10; 3.5 and 5; 5.5 ppm and 0 Kgf/cm<sup>2</sup> of pressure and concentration of chloride, respectively). A control treatment (initial count) was also conducted to evaluate the reduction (log<sub>10</sub>) compared to other treatments. A total of 240 chicken carcasses, 40 for each experiment with and without apparent fecal contamination, were analyzed in terms of counting of *E. coli* and *Enterobacteriaceae*, respectively. These analyses were carried out immediately after the treatments under validation, from samples of 25 g of the previously demarked area.

**Table 1. Independent variables and tested levels of the 2<sup>2</sup> factorial design**

Independent variable	Levels		
	+1	0*	-1
Dichloride concentration (ppm)	10	5	0
Pressure (Kgf/cm <sup>2</sup> )	5.5	3.5	1.5

\* Triplicate of central point.

### Microbiological analyzes

For the microbiological analyzes, 25 g of each sample was diluted in 225 mL of peptone water (Merck, Darmstadt, Germany) 0.1% (dilution 10<sup>-1</sup>) and by successive dilutions. The plating of each dilution was carried out in duplicate runs and incubated at 36±1 °C during 24±2 hrs. Counting was performed immediately after the incubation. The results were expressed as Colony Forming Units per gram (CFU/g) or by their logarithm (log<sub>10</sub> CFU/g).

The *Enterobacteriaceae* counting was performed in Petrifilm plates (3M, Sumaré, Brazil), following the methodology validated by AFNOR n° 3M 01/6-09/97 and Normative Instruction n° 62, 26/08/03 - MAPA (Brasil, 2003b). The *Escherichia coli* counting was carried out also using the Petrifilm plates, by the methodology validated by AOAC 998.08 and 991.14 and Normative Instruction n° 40, 12/12/05, MAPA (Brasil, 2005).

### Evaluation of visual aspect

The evaluation of the visual aspect of the chicken carcasses (A - without apparent contamination and B- with apparent contamination) was carried out using the paired test (Meilgaard *et al.*, 1987), collecting samples after the spray-washing (5.5 Kgf/cm<sup>2</sup>, without addition of dichloride). Thirty-two non-trained

judges, both sexes, different ages (20 to 50 years old) participated in this step. The samples of chicken carcasses were presented side by side in plastic coded recipes with random numbers and indicated the code of the sample with higher apparent contamination detected visually.

### Statistical analysis

The results of the microbiological determination (validation experiments) were submitted to the analysis of variance, followed by Tukey's test for comparison between mean of the results, at the significance level of 5% ( $P < 0.05$ ). The data obtained in the experimental design was treated by the Software STATISTICA version 7.0 (StatSoft Inc<sup>®</sup>, USA).

The visual characteristics of the chicken carcasses were treated and analyzed by  $\chi^2$  distribution (Meilgaard *et al.*, 1987), to establish the presence or lack of a significant difference ( $P < 0.05$ ) as a function of the number of total judges and number of judges that agreed.

### Results

Initially, we have analyzed the chicken contamination, simulating the disruption of the guts (by adding a large amount of fecal contamination to the carcasses after the evisceration). The objective was to determine the maximum quantity of *E. coli* and *Enterobacteriaceae* present on the skin and compare it with the part without visible fecal contamination.

The initial counting of *E. coli* for contaminated and non-contaminated carcasses presented values of  $3.5 \times 10^6$  and  $3.3 \times 10^3$  CFU/g, respectively. The initial counting of *Enterobacteriaceae* for contaminated and non-contaminated carcasses were  $6.3 \times 10^6$  and  $4.6 \times 10^3$  CFU/g, respectively. The reduction of contamination evidenced between the contaminated and non-contaminated skin was of 3 log<sub>10</sub>.

Table 2 presents the matrix of the 2<sup>2</sup> experimental design (real and coded values) and the responses in terms of *E. coli* (with and without contamination) and *Enterobacteriaceae* (with and without contamination), after the washing using different levels of pressure and dichloride concentration. From this table, one can verify that experimental conditions of treatments 2, 4 and 5 to 7 (central point) presented lower levels of contamination for *E. coli* and *Enterobacteriaceae* with and without visible contamination.

The results demonstrated that the spray-washing using pressure of 5.5 Kgf/cm<sup>2</sup> without the addition of chloride (treatment 2) reduced the initial contamination of *E. coli* with contamination from  $3.5 \times 10^6$  to  $4.2 \times 10^2$  CFU/g, *E. coli* without contamination from  $3.3 \times 10^3$  to  $2.1 \times 10^2$  CFU/g, *Enterobacteriaceae* with contamination from  $6.3 \times 10^6$  to  $7.1 \times 10^2$  CFU/g and *Enterobacteriaceae* without contamination from  $4.6 \times 10^3$  to  $5.7 \times 10^2$  CFU/g, respectively.

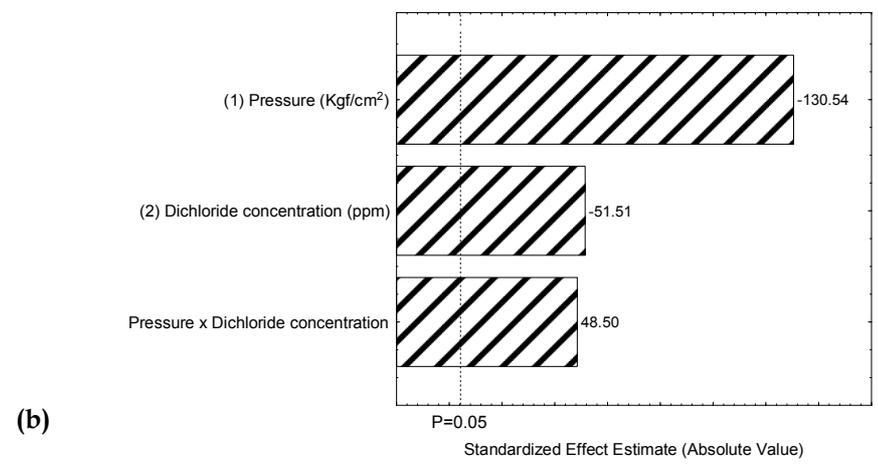
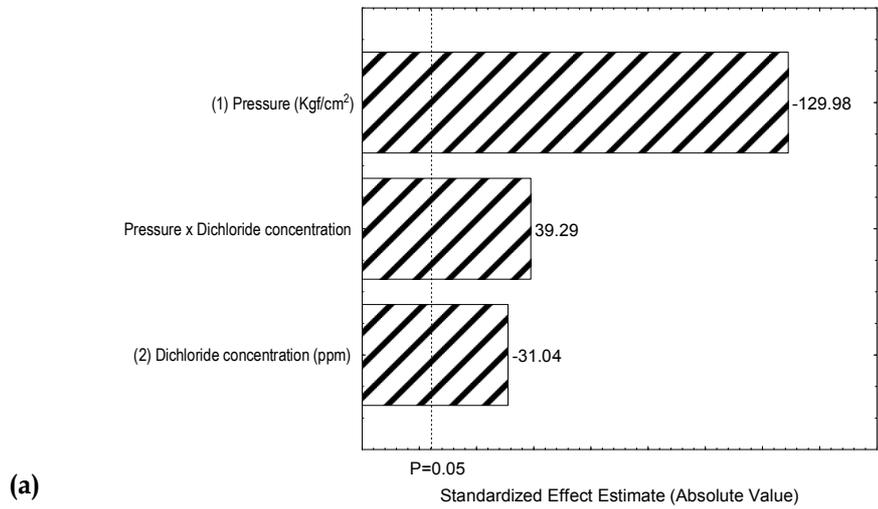
**Table 2. Matrix of the 2<sup>2</sup> factorial design (real and coded values) with the responses in *E. coli* and *Enterobacteriaceae*, with and without contamination, after the washing**

Run	Independent variables*		Response			
	X <sub>1</sub>	X <sub>2</sub>	<i>E. coli</i>	<i>E. coli</i>	<i>Enterobacteriaceae</i>	<i>Enterobacteriaceae</i>
			with contamination CFU/g (log)	without contamination CFU/g (log)	with contamination CFU/g (log)	without contamination CFU/g (log)
1	-1 (1.5)	-1 (0)	2.1x10 <sup>3</sup> (3.3)*	2.0x10 <sup>3</sup> (3.3)	4.1x10 <sup>3</sup> (3.6)	3.4x10 <sup>3</sup> (3.5)
2	1 (5.5)	-1 (0)	4.2x10 <sup>2</sup> (2.6)	2.1x10 <sup>2</sup> (2.3)	7.1x10 <sup>2</sup> (2.8)	5.7x10 <sup>2</sup> (2.7)
3	-1 (1.5)	1 (10)	1.4x10 <sup>3</sup> (3.1)	1.0x10 <sup>3</sup> (3.0)	3.7x10 <sup>3</sup> (3.6)	2.7x10 <sup>3</sup> (3.4)
4	1 (5.5)	1 (10)	5.0x10 <sup>2</sup> (2.7)	1.8x10 <sup>2</sup> (2.2)	9.0x10 <sup>2</sup> (2.9)	6.4x10 <sup>2</sup> (2.8)
5	0 (3.5)	0 (5)	2.9x10 <sup>2</sup> (2.5)	2.0x10 <sup>2</sup> (2.3)	1.0x10 <sup>3</sup> (3.0)	6.7x10 <sup>2</sup> (2.8)
6	0 (3.5)	0 (5)	2.8x10 <sup>2</sup> (2.4)	1.9x10 <sup>2</sup> (2.3)	1.0x10 <sup>3</sup> (3.0)	6.5x10 <sup>2</sup> (2.8)
7	0 (3.5)	0 (5)	3.0x10 <sup>2</sup> (2.5)	2.1x10 <sup>2</sup> (2.3)	1.0x10 <sup>3</sup> (3.0)	6.8x10 <sup>2</sup> (2.8)

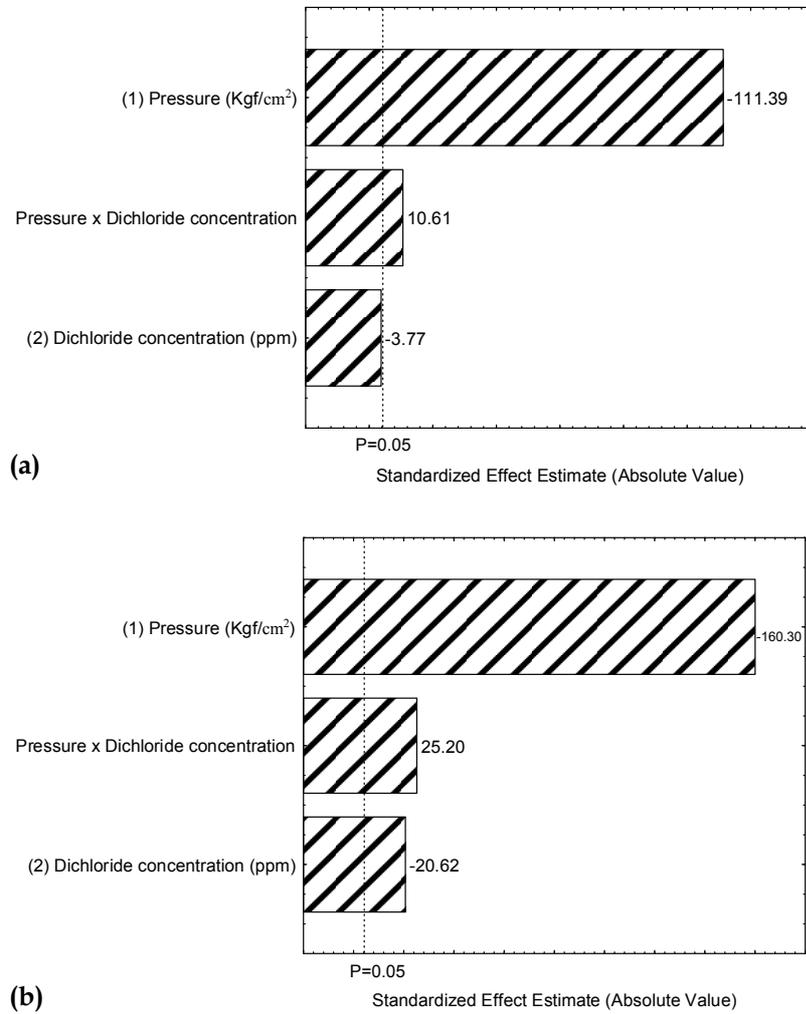
\* X<sub>1</sub>= Pressure (Kgf/cm<sup>2</sup>); X<sub>2</sub> (ppm of free chlorine)=Chlorine concentration; Fixed independent variables: Water flow: 1.5 liters/chicken; Water temperature: 18°C; Speed through the equipment (washing douche): 2.5 seconds; Number of sprinklers: 24 (12 of each side: 06 directed to the internal washing and region of abdominal opening and 06 directed to the washing the chest and back of the carcass); distance between the sprinklers and the carcass: 205 mm, length x width x height of the local where the sprinklers are inserted: 300 x 55 x 140 cm and length x width x height of the douche (measure of the sprinklers): 133 x 50 x 26 cm. \* Number of log<sub>10</sub> CFU/g reduction.

In a general way, a reduction on the counting of carcasses previously contaminated in an order of 4 log<sub>10</sub> was observed compared to the mean initial counting. In the carcasses without visual contamination, a reduction of about 1 log<sub>10</sub> was verified in comparison to the initial counting. Similar results were obtained using pressure of 5.5 Kgf/cm<sup>2</sup> and 10 ppm chloride (treatment 4) and pressure of 3.5 Kgf/cm<sup>2</sup> and 5 ppm chloride (treatments 5 to 7).

To better visualize the effect of independent variables (pressure and chloride concentration), Figures 1 and 2 present the Pareto chart with the estimated effects (absolute values) of studied variables, for the counting of *E. coli* and *Enterobacteriaceae* with contamination (a) and *E. coli* and *Enterobacteriaceae* without contamination (b), respectively. One can verify that the studied independent variables and their interaction presented a significant effect (P<0.05) under the counting of *E. coli* and *Enterobacteriaceae* in the carcasses with and without previous contamination, demonstrating that an increase in the levels of these variables leads to a tendency of reducing the microbial counting.



**Figure 1. Pareto chart with the estimated effects (absolute value) of the variables tested in the 2<sup>2</sup> factorial design, for the counting of *E. coli* with (a) and without (b) contamination, respectively.**



**Figure 2. Pareto chart with the estimated effects (absolute value) of the variables tested in the 2<sup>2</sup> factorial design, for the counting of enterobacteria with (a) and without (b) contamination, respectively.**

Taking into account the results presented above, experiments of validation were carried out for the conditions that conducted to better results (treatments 2, 4 and 5). Table 3 presents the results obtained for counting of *E.coli* and *Enterobacteriaceae* in carcasses with and without previous contamination. One can observe that no significant difference ( $P>0.05$ ) was observed for all assays.

However, a significant difference ( $P<0.05$ ) can be observed among the treatments (Table 3), related to the initial contamination of the carcasses. The washing shower using pressure of 5.5 Kgf/cm<sup>2</sup> and 10 ppm chloride reduced the initial contamination of *E. coli* and *Enterobacteriaceae*. A reduction of about 3 log<sub>10</sub> was observed for the carcasses with previous contamination. A lower reduction (0.45 log<sub>10</sub> and 0.23 log<sub>10</sub>) was observed for *E. coli* and *Enterobacteriaceae* without contamination, respectively.

The spray-washing using pressure of 5.5 Kgf/cm<sup>2</sup> without the dichloride addition reduced the initial contamination with *E. coli* and *Enterobacteriaceae* of carcasses contaminated in 3 log<sub>10</sub>, while the carcasses without contamination showed a reduction of 0.32 log<sub>10</sub> and 0.30 log<sub>10</sub> for *E. coli* and *Enterobacteriaceae*, respectively. Similar results were obtained using 3.5 Kgf/cm<sup>2</sup> and 5 ppm chloride.

**Table 3. Validation of runs 2, 4 and 5 of the 2<sup>2</sup> factorial design with the responses in *E. coli* and *Enterobacteriaceae*, with and without contamination**

Run/Variable			Microbiological analysis*			
Run	Pressure (Kgf/cm <sup>2</sup> )	Dichloride concentration (ppm)	<i>E. coli</i> with contamination CFU/g (Log reduction)	<i>E. coli</i> without contamination CFU/g (Log reduction)	Enterobacteriaceae with contamination CFU/g (Log reduction)	Enterobacteriaceae without contamination CFU/g (Log reduction)
2	5.5	10	2.7x10 <sup>3</sup> b ± 1.2x10 <sup>2</sup> (3.1)	1.2x10 <sup>3</sup> b ± 1.5x10 <sup>2</sup> (0.4)	4.3x10 <sup>3</sup> b ± 1.7x10 <sup>2</sup> (3.2)	2.7x10 <sup>3</sup> b ± 1.4x10 <sup>2</sup> (0.3)
4	3.5	5	2.8x10 <sup>3</sup> b ± 1.9x10 <sup>2</sup> (3.1)	1.8x10 <sup>3</sup> b ± 2.2x10 <sup>2</sup> (0.2)	5.4x10 <sup>3</sup> b ± 2.6x10 <sup>2</sup> (3.1)	2.9x10 <sup>3</sup> b ± 1.1x10 <sup>2</sup> (0.2)
5	5.5	0	2.4x10 <sup>3</sup> b ± 2.3x10 <sup>2</sup> (3.1)	1.6x10 <sup>3</sup> b ± 1.0x10 <sup>2</sup> (0.3)	3.0x10 <sup>3</sup> b ± 3.1x10 <sup>2</sup> (3.3)	2.3x10 <sup>3</sup> b ± 1.6x10 <sup>2</sup> (0.3)
(1)	0	0	3.5x10 <sup>6</sup> a ± 1.9x10 <sup>4</sup>	3.3x10 <sup>3</sup> a ± 1.2x10 <sup>2</sup>	6.3x10 <sup>6</sup> a ± 3.7x10 <sup>4</sup>	4.6x10 <sup>3</sup> a ± 1.1x10 <sup>2</sup>

\*(1) Initial contamination; \* Medium ± Standard deviation (Log<sub>10</sub> reduction in relation to initial contamination). Countings on the columns followed by equal letters do not indicate a significant difference at 95 % of confidence (Tukey's test).

Table 4 presents the results of the visual characteristics of chicken carcasses, indicated by a group of judges who analyzed chicken carcasses with and without visible contamination.

The test was evaluated by 32 judges. Seventeen judges observed visual characteristics of the apparent contamination on the carcasses previously contaminated. Fifteen judges did not observe a difference between the contaminated and non contaminated carcasses. From the  $\chi^2$  distribution table (Meilgaard *et al.*, 1987) one can conclude that no significant difference ( $P < 0.05$ ) was observed among the carcasses, as at least 22 concordant responses were necessary to indicate differences at 95% of confidence level.

**Table 4. Paired directional test to indicate differences between contaminated and non contaminated carcasses after washing**

Total of judges	Responses		$\chi^2$ distribution
	No apparent contamination	With apparent contamination	
32	15	17	$P < 0.05$

## Discussion

The Hazard Analysis and Critical Point system (HACCP) for chicken slaughter are similar, with the same critical control points along the process. One of these points is the removal of visible contamination after the evisceration. Based on these aspects, the results (microbiological and of visual aspect) presented here are referred to the fecal contamination in chicken carcasses, after the evisceration line and the influence of the washing conditions at the end of this step before the cooling system.

The carcasses can be contaminated during the slaughter by the liberation of intestinal content of chicken (NACMCF, 1994). Here the problem is the non-uniformity of size of the carcasses and the fact that some viscera can be damaged by the equipments (FAO, 2010). The disruption of chicken guts can be minimized, but never completely avoided. The index of contamination of the carcasses can be reduced using strategies of control under the equipments and the water diet of the chicken. To minimize the contamination of the carcasses, control measures can include the washing of the carcasses using potable water in abundance, chemical decontaminants and other physical methods approved by the competent authorities (FAO, 2010).

The results obtained here corroborate those presented by Notermans *et al.* (1980). These authors describe that the pressure increase with washing, by a series of sprays during the evisceration step, reduces significantly the microorganisms present in the chicken carcasses.

The experiments of validation were conducted taking into account the better results of the experimental planning (treatments 2, 4 and 5). No significant

difference ( $P < 0.05$ ) was observed for all assays. This result also corroborates with the data of Bilgili *et al.* (2002). They did not observe significant difference in the counting of microorganisms with and without visible contamination, after washing carcasses. Gill (2004) reported that while the spray-washing eliminates the visible contamination, the microbiological contamination can keep unaltered. Gorman *et al.* (1995) showed that the cut of meat was as effective as the spray-washing.

Higher reductions were observed in carcasses with previous contamination, comparing the initial contamination. However, no significant differences ( $P < 0.05$ ) among the counting of *E. coli* and Enterobacteriaceae was observed after the treatments, demonstrating that the results after the washing are equivalent.

The same behavior was observed in the sensory test of appearance of the products, where the carcasses with and without apparent contamination, after washing (5.5 Kg/cm<sup>2</sup>, without chloride), did not present visible detectable aspects ( $P < 0.05$ ) by the consumers, indicating that washing of the carcasses was equally satisfactory, equivalent to the skin removal, without the needs of manpower, reducing possibilities of cross-contamination due to handling, making easier the process of chicken slaughter.

The counting of mesophilic microorganisms of re-processed carcasses were slightly smaller compared to the inspected ones, in 4 of 5 evaluated plants. The same behavior was observed for coliforms and *E. coli* counting. These results are in agreement with those from Waldroup *et al.* (1993), which concluded that carcasses with visible contamination can present equivalent microbiological quality, if submitted to washing. Powell *et al.* (1995) also observed that, after the final washing, the frequency of *Salmonella* in chicken carcasses with visible contamination was not significantly higher compared to the inspected carcasses. Jimenez *et al.* (2002) compared the frequency of *Salmonella* in chicken carcasses with and without visible contamination during the commercial slaughter. The study revealed that carcasses without visible contamination can have *Salmonella* as those with visible contamination after evisceration.

These results are in accordance to those from Kemp *et al.* (2001). These authors seek to determine if the continuous processing could substitute the removal of contaminated carcasses from the evisceration line. The results showed that the microbiological quality of contaminated and washed carcasses in continuous processes were higher than the re-processed out of the evisceration lines ones. The frequency of *Salmonella* on the carcasses under the continuous processing was 10%. The re-processed carcasses present an incidence of 31.6%. The authors verified that only 0.2% of 1,127 carcasses, submitted to the continuous treatment, did not attend the tolerance zero.

This evidence demonstrates no need of cutting the carcasses. This fact was also observed by Kemp *et al.* (2001), where the contamination of carcasses by *E. coli* after evisceration was 2.87 log<sub>10</sub> CFU/g, decreasing to 2.27 log<sub>10</sub> CFU/g after the continuous washing process, and 2.37 log<sub>10</sub> CFU/g in the processing with the

previous removal of faecal contamination.

The results presented above are in agreement with the recommendation of International Commission on Microbiological Specifications (ICMSF, 1998), which indicates that in case of cut and rupture of the gut during the evisceration, the carcasses should be washed to eliminate the visible contamination. This practice can reduce the enteric bacteria (coliforms, *E. coli* and *Salmonella*, as an example) until counting found in carcasses without apparent contamination.

Notermans *et al.* (1980) say that if the bacterial contamination occurs during the evisceration a maximum reduction on the number of microorganisms will be obtained if the carcasses were washed immediately after the occurrence of the contamination.

Bolder and Putirulan (2006) relate the importance of drying the carcasses in an intermittent way, to remove undesirable residues as feathers, blood and feces and, at the same time, reduce the number of microorganisms in about 1 log cycle, in agreement with the results presented in this work. The data presented here are also in agreement with Bilgili *et al.* (2002). The authors compared the microbiological quality of 1,080 chicken carcasses, with and without visible contamination, slaughtered in 7 different industries. The carcasses were withdrawn from the evisceration line, after final washing before the entry of carcasses in the pre-cooling tank and after cooling by immersion. The authors verified a reduction in total aerobes microorganisms from 4.22 to 3.27 log CFU/mL. The *E. coli* counting was from 2.36 to 1.22 log CFU/mL and *Campylobacter* from 1.69 to 0.83 log CFU/mL. The frequency of isolation of *Salmonella* decreased from 20.7 to 5.7%.

Escudero-Gilete *et al.* (2005) studied the washing of chicken carcasses using pressurized water to reduce the superficial contamination and verified that the contamination decreases significantly due to the effect of washing and water pressure. The area of washing was of 225 cm length, containing 4 blocks with 32 nozzles in different directions. The carcasses were washed during 8 seconds (2 seconds each block). The authors relate that largest decreases were obtained for carcasses with higher initial contaminations, especially for total counting and Enterobacteriaceae. These results are inferior to those obtained in the present work (Table 2). The authors suggest that pressures higher than 2 Kgf/cm<sup>2</sup> are not necessary. These results diverge from those obtained in present study, where we could verify that better results were at pressures higher than 3.5 Kgf/cm<sup>2</sup>. This fact can be associated to the exposure time of the carcasses, as the Brazilian slaughterhouses work at process velocities of about 140 chickens per minute.

Northcutt *et al.* (2007) used a chamber of 91×91×76 cm, 3 sprinklers of each side and pressure of 552 KPa, solution of sodium hypochlorite 50 ppm during 5, 10 and 15 seconds. The authors verified reduction on total counting of bacteria, *E. coli*, *Campylobacter* and *Salmonella*, when time was increased from 5 to 10 seconds (0.3, 0.5, 1.0 and 0.8 log<sub>10</sub> CFU/mL, respectively).

In our study (Tables 2 and 3), the best results were for *E. coli*, even when the

lowest amount of technological adjuvant was used. Probably this result is associated with the higher number of sprinklers, despite the shorter exposure time (2.5 seconds). In our case, a chamber with external dimensions of 300×55×140 cm and shower dimensions of 133×50×26 cm, with 24 sprinklers was used. The microbial reduction demonstrated in our study is of extreme importance since carcasses visually contaminated with residues do not have access to the cooling tank.

### Conclusions

The results of this work showed no significant differences between the carcasses with and without initial apparent fecal contamination after passing through the washing nozzles, related to the *E. coli* and *Enterobacteriaceae* counting and the visual characteristics of the products. The binomial pressure-adjuvant concentration influenced the result of microbiological analyses of chicken carcasses, the pressure demonstrated higher influence compared to the adjuvant concentration. Most of the treatments showed satisfactory results on the fecal decontamination.

The removal of visible fecal contamination of chicken carcasses using potable water, in an adequate way, beyond legal, used and accepted by most exporters and importers of chicken meat, can contribute to maintaining the microbiological quality of the products and also minimizes the economical losses to the poultry sector.

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