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Bacterial Dissemination. Main Pathogens and Hygiene in Chicken Slaughter: A Review[1]

Ronaldo de Oliveira Sales[2], Ernani Porto[3]

SUMMARY: In this bibliographical review, the different types of bacterial dissemination are presented, as well as the main pathogenic bacteria involved in chicken slaughter. The influence of hygiene in chicken slaughter upon storage and sale conditions on the retail market is also discussed.

Key words: Bacterial dissemination, packing, chicken slaughter.

Desseminação Bacteriana. Principais Patogenos e Higiene no Abate de Frangos: Uma Revisão[1]

RESUMO: Nesta revisão bibliográfica são apresentados os diferentes tipos de disseminação bacteriana, como também as principais bactérias patogênicas envolvidas no abate de frangos. Discute-se ainda a influência da higienização nas condições de armazenagem e de comercialização no abate de frangos no mercado varejista.

Palavras-chave: Disseminação bacteriana, embalagem, abate de frangos.

[1] Work carried out at Campinas State University - SP (UNICAMP).
[2] Professor, Doctor, Address for Correspondence: Zootechnical Department, Agrarian Sciences Center, Ceará Federal University, Caiza Postal 12.168, Fortaleza - Ce, CEP: 60.335-970, Brazil
[3] Food Technology Institute - ITAL; CP 139; CEP: 13.073-001; Campinas-SP.

Introduction

The breeding and consumption of chickens has undergone continuous growth in recent decades. Together with this, slaughter and processing of chickens has been increasing and changing rapidly in accordance with the increase in the population of large urban centers, which consume a proportionately larger quantity of chicken, with the primary factor being infra-structure, such as conservation and distribution, essential factors, in order that the process of slaughter and retain become more efficient. The fast pace of slaughter, and the large volume of consumption, have increased the problem of bacterial contamination, both from the point of view of public health, and that of the perishability of the product, the hygienic aspects of this process taking on an ever greater importance in the productive chain. In addition to the aforementioned aspects, commercialization of chicken cuts and the use of chicken meat as a total or partial raw material in sausage products, fillings, etc. This additional manipulation and transport offers new gateways for bacteriological contamination and for dissemination and proliferation of the bacteria originating from the slaughter and commercialization process. Prevention is the most economic and efficient means of obtaining a microbiologically healthy and safe product, and for this end, it is necessary to have knowledge of the stages of chicken slaughter, their main critical points and pathogens associated with the slaughter process.

2 - Stages of the Process

The slaughter of chicken has its own characteristics, peculiar to the animal and form of production, the breeding of chicken for meat being a highly intensive process, a characteristic which extends into slaughter. The speed of slaughter is measured in thousands of birds per hour, reaching rates above 4,000 birds/hour. From the farm, the chickens are transported to the slaughterhouse in trucks, inside plastic or wooden cages, where the birds are transported in groups of approximately 10 per m^2. After arriving at the site of slaughter, the birds remain for a relatively short period, awaiting unloading. They are unloaded and enter the slaughter line, at the end of which a refrigerated chicken carcass, frozen, in cuts for the consumer or industrial utilization is obtained. Within this last stage, Mechanically Separated Meat (CMS) production has already begun, starting with cuts of low commercial value (spine, neck), or leftovers from boning (gizzard, etc.).

The main stages of the process are as follows:

2.1. Bleeding
2.2. Scalding
2.3. Plucking
2.4. Evisceration
2.5. Chilling

2.1. Bleeding: can be done with or without prior stunning. Stunning is done with low (70-100V) or high (500V) electricity, care being taken not to kill the bird thus avoiding compromising of bleeding. This stage is performed either by cutting the jugular vein or by perforation of the palatal cleft, when the blood flows through a bleeding tunnel for dripping of blood until death. The duration of the process is calculated as a function of the number of birds per slaughter cycle, generally taking about 3 minutes.

2.2. Scalding: consists of immersion of the carcass in a tank of agitated hot water, it being important that the bird doesn't enter the tank alive, so as not to breathe water and contaminate the interior of the organism, via the lungs. The scalding process, seeks to facilitate the removal of feathers, recommended temperatures varying between 50^{o}C and 80^{o}C. Lower temperatures (light scalding) will result in longer plucking times, but less alterations in the visual aspect of the carcass will occur, whilst higher temperatures reduce plucking time, but alter the visual aspect of the carcass more, leaving it more discolored.

2.3. Plucking: feather removal operation, executed by a set of three machines, containing several discs containing rubber fingers which rotate around both sides of the carcass, removing the feathers. Cleaning water is constantly projected over the equipment to remove feathers. The duration of the process may be shorter or longer, depending on the previous stage.

2.4. Evisceration: may be manual or automatic. It begins with opening of the cloaca with a vacuum pistol, after which the abdominal cavity is opened, exposing the viscera, from which the giblets are removed, as are the lungs, using suction. In this stage, extreme care must be taken to avoid bursting the intestines and contaminating the carcass with fecal material.

2.5. Chilling: In this stage the temperature of the carcass should drop from 30^{o}C to 40^{o}C, this being possible in two ways: a) Immersion (spin chiller); b) cold air (spray chiller).

Immersion ("spin-chiller"): generally consists of a series of 2 tanks, one for pre-chilling and the other for chilling, containing

water and ice, the carcasses being carried by an endless screw thread. In this process, the carcasses absorb water and gain weight, and should be allowed to drip for a certain time after leaving the tank so that the increase is excessive. This is the process used in Brazil and the United States, having a lower cost in relation to the "spray-chiller".

Cold Air ("spray-chiller"): consisting of tunnels of cold air through which the carcasses lose weight through dehydration, possibly acquiring a more dried-out appearance; nevertheless, it is considered by some to be more hygienic than the previous method. It is also widely used in Europe, despite the slightly higher cost.

3. Critical Points

Bacterial dissemination can occur in all stages of the process. Equipment, utensils, employees, birds, water and air take part in bacterial dissemination. The bird arrives at the slaughter location with all its own contamination and that which it acquires during transport. Even if all stages could in some way contribute to this event, some stages are particularly decisive as they present characteristics which make them amplifiers or incubators for bacterial contamination (LONG, 1982; MCDOUGALD & REID, 1991).

3.1. Scalding

Austic & Scott (1991), identify it as one of the most important foci of cross contamination. Water from the scalding tank accumulates a large quantity of organic material and dirt originating from the birds' body. In addition, the birds generally defecate through a reflex action during the process of immersion, adding more material to the tank. Due to the characteristics of the bird's feces, chemical reactions occur, leaving the water's pH at levels which favor bacterial survival, due to the increase in their capacity for heat resistance.

BENEDICT (1988), shows that scalding is one of the main critical point in the slaughter of chicken. The author, inoculating birds before scalding with a strain marked *Escherichia coli*, studied caused cross contamination and its consequences. When the bird was externally contaminated, passage through the scalding tank ($62^{o}C/120sec$) produced a sharp drop in contamination, of around three logarithmic cycles. On the other hand, the passage of this inoculated bird through the tank is capable of contaminating 230 birds which passed through the tank before it. The author concludes that scalding washed the carcasses bacterial load, leading to the reduction of microbe counts in the

inoculated bird and contaminated the others through the water. (TABLE 1).

Table 1. *Escherichia coli* counts before and after scalding and plucking, following passage from an externally contaminated chicken (cont./ml of washing in log. Base 10).

Pre-scalding Count	7.95		
Sampling point			
		Post-scalding	Post-plucking
Contaminted bird count		4.86	4.70
Contamination of the first 230 chickens.	1	3.36	5.40
	2	1.72	2.97
	3	1.59	2.53
	4	1.95	2.53
	5	-	1.99
	10	3.43	1.51
	20	1.18	1.90
	30	1.41	1.76
	40	1.00	1.41
	50	1.20	1.00
	170	1.04	-
	230	1.57	-

Source: AUSTIC & SCOTT (1991)

The same author inoculated the marked bacterial via cloaca, and determined the effect of passing this bird through the tank. In this case of internal contamination, bacterial dissemination is much lower, being limited to the detection of *Escherichia coli* in only 50 of the later birds (SOJKA, 1965).

Following contamination in the scalding tank, the micro-organism is detected in all stages of the process, and the greater the number of contaminated carcasses to be found upon leaving the chilling tank (SOJKA, 1965).

Whiteman & Bickford (1989), studied the differences in behavior of entero-bacteria in the face of scalding temperatures, arriving at the following conclusion. If the entero-bacteria are not attached to the chicken skin,

there is a steep drop in the counts. However, once attached, their thermal resistance increases enormously, and destruction rates are no longer logarithmic. There is also a difference in contamination pre- and post-scalding. Prior to scalding, bacteria attach, remaining on the chicken, their removal proving difficult whilst contamination from scalding is easily removed.

BERCHIERI JR (1987), found that *Salmonella* bacteria show the greatest survival rate in scalding water at the end of the slaughter cycle, when there is a large accumulation of organic material and pH of 5.9, than at the beginning of the day, with cleaner water and a pH of 7.6.

The accumulation of material, especially protein and alteration in pH should be responsible for the increase in bacterial survival, increasing the risks of cross contamination

3.2. Plucking machine

SKEELES (1991), DODD et al. (1988a b) refer in some papers, that this stage shows large and important contamination points responsible for bacterial dissemination.

In the work of AUSTIC & SCOTT (1991), with a strain marked *Escherichia coli*, the author shows that external artificial contamination of a bird, prior to scalding, is eventually detected in many birds which subsequently go to plucking. The plucking equipment proves to be successful in expanding the contaminant load of the carcasses which left scalding contaminated, with the plucking machine spreading and increasing the external contamination of the carcasses (TABLE 1). The same author also refers, with regard to the hot water operation (55^{o}C), to removal of feathers accumulated in the equipment, where contamination diminished.

SKEELES (1991) identifies the plucking machine as the main cause of contamination of the carcasses by *Staphylococcus aureus*, detecting in fact, strains which would be endemic, inhabitants of the 'fingers' of the equipment. Identified by phago-typing, the strains show that there is a switching of predominant strain in the plucking stage. Scalding would reduce counts, and these would once again increase after plucking, as during passage through the plucking machines, there would be substitution of phago-types and introduction of new ones, completely altering the contaminant profile existing in the bird prior to these stages (TABLE 2). The same author finds similar results, with an increase in typical colonies of *Staphylococcus aureus*

after passing through plucking machines. However, capacity to colonize the equipment was observed by the same author, who followed the modifications resulting form installation of new equipment in a slaughterhouse. After introduction of the machine, it was soon colonized by strains of *Straphylococcus aureus.* After 17 days the bacteria could already be found in the first two machines, and after 38 days, all three machines were contaminated. WILLEMART (1980) concludes that, apparently, entero-bacteria would have the same capacity for colonization, however, CHERRINGTON et al. (1988), failed to find persistence of soro-types of *Escherichia coli* isolated in the equipment, concluding that there is no such capacity.

Table 2 - Phagotype counts in aviaries with *Staphylocuccus aureus* (ufc/4cm2 of 'finger') isolated in plucking machines (A=1st machine, B=2nd machine. C=3rd machine).

	Pre-processing count	Count at 2 hours into process	No. of isolated chicken	No. of phago-types (+frequency)		
Point				B1	B2	C
A	$1.0x10^2$	$9.0x10^3$	24	1	5	13
B	$2.5x10^3$	$4.5x10^6$	119	13	20	56
C	$1.2x10^3$	$3.7x10^3$	41	12	0	23

Source: SKEELES (1991)

One of the causes of bacterial survival in accordance with SKEELES (1991), would be the conditions offered by the equipment which, being near the scald tank, receives steam, having good temperature and humidity conditions. The accumulation of feathers during the process would also favor survival of S. aureus. HEAD (1986) suggests as a further factor, the difficulty in attaining effective cleaning of this equipment, and the characteristics of scratches and cracks in the rubber 'fingers', contributing to the process.

3.3. The Chiller

This is the last stage in the process, from which the carcasses leave for consumption. Contamination in this location will be carried to the consumer and will influence the shelf life of the product, there

being some debate about the most hygienic method, whether spray of immersion of carcasses. One of the serious problems with using immersion would be the effect of removal of bacteria by washing of the chicken carcass, and subsequent recontamination of the other uncontaminated carcasses. Although numerically this contamination may not become serious and is controllable, it gains importance when one is dealing with pathogenic bacteria, where the mere presence of some cells may represent a health risk to the population. And this transfer is extremely difficult to control. Effectively, there are those who profess that the immersion method is hygienically unacceptable. This is the position of the European authorities.

With regard to this issue, BAILEY (1986) found that the use of spray chillers only contaminated carcasses which were near heavily contaminated ones. The same authors concluded that this method would cause as much contamination of carcasses as immersion, however, the same two authors studied two types of chilling in use and others still in the experimental stage, concluding that the immersion system is even more appropriate, economical and ecological (using lower quantities of water per carcass), and provides a more aesthetically pleasing product. With appropriate hygiene measures, the micro-biological aspect is no more problematic than that of other methods. The same authors also found large reductions in entero-bacterial counts, irrespective of the chilling method used, as the high carcass contamination would be cause by high bacterial counts in the tank, whilst carcasses with low contamination prior to immersion, leave the process with a low contamination level, this being much more a problem of micro-biological quality of the carcasses which enter the tank, than of the process itself (GILARDI, 1985).

BLOOD & JARVIS (1974) studied the different chilling conditions for immersion arriving at the following conclusion: When a small quantity of water is used per carcass ($1dm^3/100g$) with moderate chlorination (6-18ppm), or moderate quantities of water (3.6-$4.8dm^3/100g$) with low chlorination (5-8ppm), aerobic bacterial levels were of around 10^5 ufc/ml and coliforms in the region of 10^3-10^5 ufc/ml. Therefore, when greater quantities of water were used with higher chloration (12-46ppm), contamination fell below detectable levels.

BERCHIERI JR (1987), working with chickens in contamination concluded that this stage of the process would be a factor of relevance, for example, to *Salmonella* and other pathogens, possibly contaminating other carcasses, even if the number is lower. Reduction would occur through washing the carcasses, diluting individual contamination, but passing on to others. For this not to

happen, chlorination should be effective to eliminate bacteria in the free water identified as an important point of cross contamination (BAILEY, 1986).

BERCHIERI JR (1987) found reduction of psychrophyllic micro-organisms during the chilling stage, and also in redistribution through the carcasses, but was unable to detect pathogenic bacteria in the chilling process, supposing that the effect would be the same. The same author emphasizes that the washing of carcasses before and after immersion, is effective in reducing bacterial contamination, due to the reduction of contamination entering the tank and through removal of the contamination acquired therein, and water should be chlorinated for elimination of bacteria which are removed during the process.

BAILEY (1986) also refers to the phenomenon of washing carcasses whereby bacteria return to other carcasses, during immersion in the chilling tank. In relation to aerobic micro-organisms, enterbacteria are 81% lower in the water in this tank. In the scalding tank, this difference is 98.8%, indicating a greater sensitivity to heat.

4 - Main Pathogenic Bacteria

4.1. *Staphylococcus aureus*

Coco G+, irregularly grouped in bunch form, not sporulated, is part of the natural micro-biotic of the skin and upper respiratory tract of humans and animals. Associated with pyogenic processes, it also produces several toxins. In foodstuffs, the most important is a protein toxin with low molecular weight and a heat-resistant cause of strong gastro-intestinal irritation in humans and some species of animals, there being at least 5 different types of entero-toxins designated by the letters A, B, C, D & E.

According to BOLTON et al. (1988) ***Staphylococcus aureus*** begins colonization of the bird's skin on its first day of life, the number of carrier birds continuously growing up until the 50^{th} week of life, when virtually all the birds in a lot are carriers. Isolations occur both on the skin and in the naso-pharynge. The predominant strain in this study was the B_2 phage.

According to SKEELES (1991) the main dissemination point for this bacteria in a slaughter house is the plucking machine, also verified by other authors, such as DODD et al. (1988 a,b), wherein the evisceration room was designated as being the point where there could be contamination, as one of the characteristics of contamination with ***Staphylococcus aures*** is a fast and widespread contamination, lasting throughout the entire process.

The work of SKEELES (1991) and DERVISE et al. (1975) demonstrate what really occurs in the units studied. During scalding, there was a drop in bacterial counts, then after entering the plucking machine, the same chickens leave with a much higher count than at entering. The strains isolated at scalding and upon entering the plucking machine, where identified by phages of types A and B. However, shortly after passing through the plucking machine, the predominant phage was type B1 and C, there occasionally being a change of strain (TABLE 3). Contamination of the carcasses was greater in the second machine, exactly the one which accumulated a greater quantity of feathers. Especially the strain of phagotype C appeared to be highly resistant to the chlorination used, remaining throughout the line thereafter, in equipment and carcasses. SKEELES (1991) concluded that the strains were not of poultry or human origin, but endemic to the equipment itself, which introduced it to the carcasses.

DODD et al. (1988 a,b) found similar results, using isolation in Baird-Parker agar jelly, noting that the atypical cultures of Staphylococcus aureus in the middle were ten times more common than typical ones, in the pre-plucking samples. The same author showed that following passage through the plucking machines, there was an inversion, with predominance of the typical over the atypical in a proportion of 20 times, showing that there is a real colonization of skin in this stage, the contamination remaining throughout the process, dropping somewhat (5-12%) upon immersion in the chilling tank.

BOLTON et al. (1988), researching at 4 different plants, isolated ***Staphylococcus aureus*** in the water in scalding and chilling tanks. Also indicating the most critical points as being the plucking machine and evisceration, independent of the point in which contamination occurs, not altering until the end. In this work, at all the points where there was an increase in contamination, a new phagoype was introduced, indicating the existence of an endemic strain. This hypothesis is supported by the fact that the same phagotypes were always encountered, even on different days and with different batches of birds. In addition to detecting greater contamination in the skin of birds processed, than in live birds, confirming that there is enormous persistence in contamination.

Table 3 - *Staphylococcus aureus* counts (ufc/16cm^2 of skin) during initial stages of the process.

Location	Count	No. of types isolated	Poultry Phagotype		
			B1	B2	C
Live bird	1.2×10^3 - 5.3×10^4	38	1	35	0
Carcass	5.0×10^2 - 1.2×10^3	32	1	27	3
Post-scald	2.8×10^3 - 4.2×10^3	48	7	15	20
1st plucking	1.7×10^4 - 1.0×10^5	47	5	4	29

Source: Skeeles, 1991

SKEELES (1991) found that following the introduction of a new plucking machine and reduction of chlorine levels in the water supply, there was a rapid increase in contamination. In the initial days, only the first machine showed contamination, but after 38 days, the bacteria had already contaminated all three machines.

According to COX (1974), of all the characteristics of endemic strains, one of the most problematic was resistance to chlorine. Although these strains are no more resistant than the others, resistance becomes highly significant given the large quantity of organic material which accumulates in the equipment, rapidly rendering inactive the chlorine in the water, and the difficulty in making significant strains reach the locations where they are to be found. Some isolated strains were able to survive, in vitro, at up to 2ppm of chlorine.

SKEELES (1991) emphasizes resistance to chlorine of the endemic strains, resulting from their capacity to grow into cell clusters. Whether or not resistance is chemical or merely physical protection, is unknown. However, the loss of clustering through ultra-sound treatment makes the bacteria more sensitive to chlorine. The capacity to form cell clusters would be an important element in its ability to colonize equipment and contaminate carcasses (DODD et al., 1988 a,b). The origin of the endemic strains would be the bird itself. They exist in the live bird, but in reduced number. Introduced into the plant, they establish themselves in the equipment and would supplant the other strains, as a result of the characteristics mentioned above.

BOLTON et al. (1988) isolated strains coming from the livers of chickens from the slaughterhouse, with this enterotoxigenic capacity are also reported by Dodd (1988b).

SKEELES (1991) found strains producing enterotoxin isolated from the skin of slaughtered birds, the type A toxin being the most predominant. Of 139 strains

originating in slaughterhouses, HARRY (1964) found that 25% of them were toxin-producing. Of these, 91.4% produced the 'D' toxin. However, strains of the 'C' phagotype (endemic) do not produce enterotoxin. There is also no production of toxin at detectable levels in chicken skin in storage temperatures (15^{o}-22^{o}C). But a these temperatures, there was an appreciable proliferation of ***Staphylococcus aureus***. Many strains are enterotoxigenic.

4.2. *Clostridium perfingens*

Stick G+ sporulated, part of the normal micro-biotic content of the intestinal tract of animals, and is a soil inhabitant. It causes processes of feeding intoxication through production of an endogenous toxin. In healthy animals, it can be found in greater numbers in the caecum and colon.

BENEDICT, R.C. (1988) and AL-SHEIKHLY et al. (1977) found a large number of micro-organisms in the feet, feathers and neck of birds. Of this large quantity of micro-organisms found in birds, a large number of samples were positive in scalding water (69.2%) and in the chilling tank (25%). The presence of these bacteria in the water results from the effect of washing contaminated carcasses, which would end up contaminating the remainder. The high presence of C. perfringens especially in the skin of the nexk region, would present some risk in the utilization of these parts as a raw material for sub-products. In the slaughterhouse, it can be isolated from all points of the process.

4.3 Campylobacter

Curved G- stick, non-sporulated, where several species form part of the type, and are involved in several pathological processes in humans and animals. Present in foodstuffs, they can cause gastro-intestinal outbreaks, as their pathogenic nature is not yet fully understood. The presence of this bacteria in chicken carcasses is considered to be a potential infection risk for humans.

Present in the gastro-intestinal tract of poultry, with enormous variations (1.8%-91%) and its presence in chicken carcasses is reported between levels of 1.7 and 82% in the USA and 14-91% in Great Britain (Gross, 1958). The same author, working in a plant which used immersion of carcasses in brine for the "Kosker" process, found that the birds of a particular serum type were not seriously contaminated upon being plunged into the tank in which the water possessed a different contaminant serum group.

Scalding was not enough for elimination of all the contaminant load of ***Campylobacter*** from chicken skin (Gross, 1966). In light scalding (52oC), this reduction

is minimal. Although very sensitive to dehydration and cold, the effect is greatly reduced in the micro-organisms in the carcass, because they provide a protective effect (Gross, 1991). However, *Campylobacter's* incapacity to reproduce below temperatures of 30^{o}C, and survive on slaughterhouse surfaces through the temperature and low humidity conditions, reduce the problem of cross contamination to a minimum, together with hygiene and cleaning which are highly effective on the micro-organism (AUSTIC & SCOTT, 1991).

GROSS (1958) studies the prevalence of ***Campylobacter*** in slaughterhouses for chicken. He isolated bacteria in the water from washing the plucking machine, cross contamination being possible via the water sprinklers. It was also isolated from water recycled within the plant, the re-use of this water possibly re-contaminating the plant. There is a large and significant difference from caecal contamination in isolations from different batches (60-100%). The washing of carcasses at the end of evisceration is efficient in reducing contamination. The chilling tank represents one of the main points for cross contamination. Isolations occur in the water, and carcasses which enter uncontaminated, leave with the micro-organism on their surface. Apparently, *Campylobacter* presents some resistance to chlorine and with lower slaughter rates, contamination is reduced.

4.4 Listeria

Corinebacteria, dyphteroid bacillus G and non-sporulated. This is involved in several pathogenic processes, capable of causing miscarriage and meningitis, however its pathogenic nature is not well understood.

AUSTIC & SCOTT (1991) state that it can be found in 60% of chicken carcasses chilled or frozen for the market. It is also capable of surviving pasteurization, being a highly resistant micro-organism, capable of growing at refrigeration temperatures. They fail to detect the bacteria in birds before or after scalding (nor in the water) nor in the plucking machine. Following the evisceration process the birds were contaminated. The only equipment which was contaminated was the automatic carcass opener. The same picture was found on three separate occasions, with 50% contamination of carcasses at the end of the process. Contamination may be directly attributed to this stage of the process, which would be compatible with the fact that it is commonly found in poultry intestines. The bacteria of the intestine contaminate the equipment directly, and cross contamination would be an inevitable problem.

4.5 Coliforms

Bacteria belonging to the group ENTEROBACTERIACEA, composed of many types. They can inhabit the environment and intestine of animals, but some are found only in the intestine. They are G- sticks, and used as indicators of hygiene and fecal contamination, although they can be pathogenic.

BLANESHIP (1975) found that the group is practically eliminated from the bird's skin by scalding at 60^{o}C, but lower temperatures have little effect on counts on the bird's surface, there being a strong correlation between E. coli and other enterobacteria, thus enabling them to be used a indicators of fecal contamination during the process, provided that scalding temperatures are high, eliminating contamination of the bird itself. Otherwise, the coliform counts will reflect pre-existing contamination, and not that acquired during the process.

The same author recommends washing carcasses with a spray for 5 seconds before they enter the chilling tank in order to remove contamination from evisceration, this washing being applied both inside and outside the carcass. Coliform counts increase during the period of the process (Harry, 1964).

SOJKA (1965) tested serum types of Escherichia coli, in slaughter houses, finding no constants in the isolations, indicating that there is no colonization of equipment as occurs with Staphylococcus aureus (Skeeles, 1991), but only contamination coming from the chicken.

AUSTIC & SCOTT (1991) working with a marked strain of E.coli, observed that the points of most contamination at the beginning of the process will influence all subsequent stages. The same author refers to cross contamination which occurs in the scalding tank, which is detected as far as the chilling tank. This contamination by coliforms occurs as a result of the bacteria outside the bird. These bacteria inoculated in the intestine would not contaminate other carcasses in the initial phases. The carcasses which were inoculated externally, invariably showed a greater bacterial count at the end of the process.

4.6 Salmonella

G- stick, not sporulated, from the group of enterobacteria, causing infectious processes in humans and animals, commonly intestinal processes. It is not considered a normal part of the intestine's micro-biotic content, but animals may be asymptomatic carriers of bacteria and eliminate it.

Salmonella, according to WHITEMAN & BICKFORD (1989) exists in all points of a slaughterhouse, except in the

water supply. Not only in poultry, it is also detected in sub-products such as tissue meal and feathers, as well as in carcasses ready for slaughter. The isolated strains showed the same resistance to antibiotics which is commonly used in poultry farming, it being believed that the birds introduce the micro-organism into the slaughterhouse, through the feather and tissue meal used in the birds' feed, and the bacteria return to the farm.

Research performed by the United States Inspection Service show that 5% of the birds which arrive at the slaughterhouse are infected with *Salmonella* -, whilst 36% of the carcasses which leave for consumption are infected with *Salmonella* + (AUSTIC & SCOTT, 1991). In the same work, the author indicates several points as being responsible for contamination by the micro-organism, believing that only one point cannot be held responsible as a cause of dissemination. Upon carrying out their work, however, they indicate that the chilling tank is an optimal location for cross contamination, where the carcasses are washed and the bacteria removed, spreading to others. The same author concludes that, of the samples of scalding water, 15.3% are positive and of the chilling water, 52.8% were positive for *Salmonella*. Nevertheless, the incidence of *Salmonella* increases following passage through the chilling tank at 15% and 28% in the plants where the study was performed (TABLE 4).

Table 4 - Incidence of *Salmonella* before and after chilling in two commercial plants.

Point of Sampling	Incidence of Salmonella (%)	
	Plants	
	A	B
Prior to Chilling	5/40	4/40
	(12.5)	(10.0)
After Chilling	11/40	15/40
	(27.5)	(37.5)

Source: AUSTIC & SCOTT (1991).

The report of high levels of contaminated carcasses in the marketplace was made by AUSTIC & SCOTT (1991), in which they report several points of cross contamination for *Salmonella*, such as the plucking machine, scalding, evisceration and chilling.

WHITEMAN & BICKFORD (1989), were able to reduce cross contamination in the scalding tank, by *Salmonella typhymurium*, maintaining a pH of 9, with a temperature of 52^{o}C, a reduction which is of interest for reduction of cross contamination in subsequent stages. The same authors state that batches possessing widespread external or internal contamination will show greater contamination at the end of the process.

5 - Hygiene

Given the huge variety of bacteria involved in chicken slaughter, a perfectly hygienic process is a highly complex task. It involves several critical points and different forms of contamination. There will be bacteria which are introduced by birds and others which are already established in the plant, awaiting the right occasion to contaminate other carcasses.

The fast pace of slaughter leads contamination to take on vast proportions. Pauses during operations are short, and the journey is long, which makes hygiene difficult, facilitating the accumulation of contaminated material. Most researchers are unanimous with regard to the fact that there is a cumulative contamination effect. The greater the contamination of live birds and in the initial stages, the greater the final bacterial load.

Lusis et al. (1971) reports the phenomenon of bacterial adhesion. All bacteria have the capacity to adhere to surfaces, including skin and muscle. Once adhered, removal becomes somewhat difficult, as they are resistant to the action of surfactants and heat. Skeeles (1991) reports that when adhered to the skin of chicken, there is an increase in the heat resistance of enterobacteria. Meanwhile, the free bacteria in the scalding water are rapidly destroyed, even though the bacteria on the skin survive the process, tending to remain there until the end of the process.

AUSTIC & SCOTT (1991) report a number of factors which may influence the process of adhesion. There is an influence of pH and temperature, but there are no differences between parts of the carcass or whole carcasses, or between G+ and G- bacteria, mobile or immobile. They all have essentially the same levels of adhesion, the chlorination of water being one of the resources most commonly used in the attempt to reduce or avoid bacterial contamination.

BERCHIERI JR (1987), studying the reduction in *Salmonella* through chlorination of water in the chilling tank, concludes that chlorine at levels of 50ppm reduced cross contamination, but was not efficient in the reduction of carcass contamination.

CHERRINGTON et al. (1988) found small reductions in contamination of

carcasses, working with chlorinated water at around 10-20 ppm in the water supply, in samples collected after spray washing of carcasses upon leaving plucking. With these levels of chlorine, the load of contaminant fell tenfold at the end of the chilling process. In any case, contamination with *E.coli* fell during the plucking and evisceration stages. The chlorine is rapidly rendered ineffective by the abundant quantity of organic material present in the equipment, but may serve to prevent the formation of bacterial slime on it. (ROSENBERGER et al. 1985).

Several levels of chlorine were also studied by BERCHIERI JR (1987). With up to 40ppm of chlorine, there were no alterations in the appearance of the carcasses. At 60ppm, strange odors were formed. In the presence of organic material, chlorine is rapidly rendered ineffective, however the use of anionic surfactants inhibits depletion somewhat. In the absence of organic material, *Salmonella* is destroyed in the concentration of 10^3 cel/ml with 20-40 ppm of chlorine during exposure for 30 minutes. In chicken meat artificially inoculated with 10^2 cel/ml, the lower levels of chlorination reduced contamination very little (SICCARDI, 1966).

Chlorine alone is not effective in destroying *Salmonella* artificially inoculated in carcasses, although it is useful in preventing cross contamination. With this logic, Bailey (1986) adds succinic acid at a concentration of 1% accompanied by heat treatment (55^oc) simulating scalding. This measure indeed proved to be effective in the destruction of *Salmonella* in the chicken, but changed the appearance of the carcasses, leaving the skin weak.

The chlorinated water spray for washing carcasses proved to be efficient in improving the microbiological quality of the chicken carcass (BAILEY, 1986). According to the same author this conclusion is found by comparing the quality of boned chickens and non-eviscerated ones, washed immediately after plucking and scalding. In 1980, the same author reduced coliform contamination to undetectable levels using 34ppm of chlorine or 5ppm of chlorine dioxide (ClO_2) in the chilling tank's water. The ClO_2 would be a more stable compound in the presence of organic material, with greater residual action in smaller concentrations, there also being a reduction in *Salmonella* contamination, but not one so drastic. With the four treatments used: 34, 20, 5 and 3 ppm, the first two underwent a significant increase in shelf life.

Bailey (1986), testing spray washing with chlorinated and non-chlorinated water on equipment, arrived at the following conclusion. Automatic evisceration machines contain a large quantity of bacteria per cm^2. When chlorination was not used in the washing water, the reduction in *Salmonella* is of 50%, and this reaches 96% with the use of

40 ppm of chlorine. The greater the amount of chlorination, the greater the drop. With 20ppm contamination is reduced 100 times in comparison with the use of plain water. The use of 40ppm reduces bacterial counts to very low levels (50 ufc/cm^2), and 70ppm of chlorine reduces the value even further (5 ufc / cm^2). It can be further concluded that the use of 20ppm of chlorine in the spray on equipment can reduce cross contamination significantly.

The attempt to reduce the micro-biological count through heat treatment of carcasses was made by COX et al. (1974). Following chilling of carcasses, they were subjected to temperatures of 24oC, 60^{o}C and 71oC, by immersion for 3 minutes. At all times and temperatures tested there was a reduction in the aerobic micro-organism counts. The reduction of contamination was not reflected in an increase in shelf life of the product, the carcasses looking cooked, which was unfavorable.

BERCHIERI JR (1987), experimented with several immersion treatments for reduction of *Salmonella* and *Coliforms* in chicken carcasses inoculated artificially with a known number of cells. Straightforward immersion in water between 18^{o}C and 20^{o}C with agitation for 10 minutes, is sufficient to dislodge 50-60% of the initial inoculate. Increasing temperature to 60^{o}C, the reduction in *Salmonella* is of 90% and that of *Coliforms* is of 99% of the initial count. Chlorination at 50ppm reduces contamination by *Salmonella* to levels of 54-78% of the initial one and *Coliforms* to 54-98%. However, with more moderate chlorination, between 200 and 500ppm, there are reductions in *Salmonella* counts of 90% and 96% respectively. Chlorination of 200ppm with 60^{o}C for 10 minutes is capable of reducing *Salmonella* by 99.9%. The same author testing immersion of carcasses in saline solution, being practical and economical, was unable to find any results justifying its use. However, the use of organic acids proved to be more promising. With lactic acid at 0.25% at temperatures of 60% and chlorination of 200ppm without altering notably the carcasses appearance.

DODD et al. (1988a), using potassium sorbate at 5% obtained a significant increase in shelf life with immersion of the carcass for 1 minute. This reduction in the total bacterial count was of around 2 log. cycles, thus controlling the growth of *Salmonella* and *Staphylococcus aureus* with treatment.

DODD et al. (1988b), tried acidifying the scalding water (52^{o}C) with acetic acid to determine the rates of destruction of *S.typhimurium, S. newport and Campylobacter jejuni* in scalding water, concluding that An acid concentration of 1% leaves a pH of 3.8, with a striking effect on the D value of Salmonella, causing however, a strong smell. A concentration of 0.2%

leaves less odor but is less effective in the destruction of bacteria. Despite this, it was considered an efficient method for the reduction of cross contamination in the scalding tank by the bacteria studied. This concentration causes a reduction of the D52 value of *Salmonella* in 1 minute, and the birds remain at least 2 minutes in the tank, reducing by 1 logarithmic cycle the counts of *Campylobacter*, also undergoing a large drop.

COX et al. (1974) evaluating the use of succinic acid and heat to increase the shelf life of chicken carcasses, concluded that concentrations of 3-5% are efficient, but cause alterations in the appearance of the carcasses.

The alteration of the pH in the scalding tank was attempted by DODD et al. (1988b), on *Salmonella* and *Campylobacter*. Neutralizing with Na OH, one reaches a pH of 9, but there is little effect on bacteria, compromising the plucking process.

6. **CONCLUSION**

There is enormous potential to be exploited in sterilization of chicken slaughter. Research has shown that there is enormous difficulty in eliminating contaminating bacteria bound to the chicken. To decontaminate carcasses to a significant degree, extreme methods have been tried, some efficient, others not. But all of them, one way or another, are still largely impractical, changing the appearance of the carcass considerably or reducing wholesomeness through the operation, such as the formation of irritant vapors.

The process of sterilization should be seen as a house wherein feet are cleaned on the mat at the entrance, and not when one leaves the house. Slaughter should concern itself with being hygienic right from the outset, it having been said that an initially large-scale contamination has a greater capacity to spread than a small contamination.

The scalding of highly contaminated poultry, is eventually a dirty process, in which birds are bathed in a contaminated medium. And plucking ends up spreading this contamination even more and finally, at chilling, there is an even more contaminated process. On the other hand, the continual removal of bacteria through the use of spray washing, prevents them from settling on the carcasses.

For generalized bacterial contamination, the solutions are extremely simple. Greater care with hygiene and the use of chlorination in the plant water and chillign enable an improvement in micro-biological quality. The great problem lies in the pathogenic bacteria where the mere presence of a few cells may put the population's health at risk. They generally obey the same rules as the others. Working with highly contaminated batches, there will always be a more contaminated

final product. The difficulty is in minimizing the transfer of cells especially at the chilling stage, with the use of chlorine being an important element for the reduction of such transfers.

The problem of *Salmonella* is very common, and extremely old, also being a chronic problem at the farm and the slaughterhouse, as there is a system in which the one supplies the other. The birds contaminate the slaughter and its sub-products and these finally contaminate the farm, through the tissue meal feed. The problem of *Listeria and Campylobacter* deserves even further study. The high levels of contaminated carcasses which reach the market and the real risk to public health have not yet been fully clarified. But as far as is known, the process of contamination is the same as that for *Salmonella*, the chilling process being an important stage for the transfers.

Of the potentially pathogenic bacteria, *Staphylococcus aureus* shows different characteristics from the others. It is a bacterium which is present in the healthy bird's skin and nasal cavity. As far as can be determined, however, it may permanently inhabit the facilities at a plant, especially the plucking machine. In this case, it would not be so much the contaminating load of the bird which would have an impact, but rather the capacity of endemic strains to transfer from equipment to the birds' skin during the plucking stage, and its capacity to resist the chlorine used. The enterotoxigenicity of endemic strains was not established in the cases reported, but this may not be taken as a general rule. The use of chicken meat in fillings and products for consumption has to consider this as an alert of possible problems.

In conclusion, the widespread problem related to pathogens and the discovery of real danger in certain groups (Campylobacter and Listeria), the minimization of transfer during stages of the process (notably chilling through immersion), the risk that certain bacteria present to public health when present in chicken carcasses and their potential for danger in the use of chicken meat as a raw material for industrial products, such as fillings and "ready to eat" products. These bacteria still represent a challenge with regard to decontamination, as well as the reduction of levels of cross contamination during the process.

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