Opinion of the Scientific Panel on Biological Hazards on the request from the Commission related to the Microbiological risks on washing of Table Eggs[1]

(Question N° EFSA-Q-2004-031)

Adopted on 7 September 2005

SUMMARY

Concerning marketing standards of eggs, Regulation no. 2295/2003, defines 2 grades of eggs (A and B) according to different physical characteristics as follows: (i) Grade A eggs ("fresh eggs" or "table eggs") should have a "normal, clean and undamaged" shell and cuticle; they will not be washed or cleaned before or after grading, and will be not chilled or treated for preservation."; (ii) Grade B eggs, i.e. eggs "which do not meet requirements applicable to eggs in grade A", may only be used by the food or non-food industries.

It is important to produce eggs that present the lowest health risks for the consumer. A major challenge is that shell eggs are considered a primary source of human salmonellosis in Europe. Egg-associated infections are mainly caused by *S.* Enteritidis.

The shell serves as a competent barrier to bacterial ingress with an array of antimicrobial properties for the egg. But it is a vulnerable package and its physical structures encourage the propagation of crack sites and so its handling following oviposition requires the minimum of trauma. Also, egg shell integrity declines with increasing bird age.

There are basically two routes by which the egg and its contents can become infected with bacteria:

1) Vertical transmission, i.e., transovarian transmission of *Salmonella* spp., especially *S.* Enteritidis, which is dependent upon the presence of infected ovaries and the migration of bacteria across the vitelline membrane into the substance of the yolk during egg formation.

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2) Horizontal transmission, which can occur both before (internal) and after (external) shell formation. Infection of the egg contents can occur from the moment of ovulation onwards until consumption. Trans-shell movement of bacteria can occur under the appropriate conditions of temperature, humidity etc. in spite of a number of defence mechanisms to limit the effects of such an event.

The practice of washing of eggs has been mainly developed to clean dirty eggs (grade B). Nevertheless, another reason for washing eggs is to improve the hygienic quality of eggs by decreasing the bacterial load on the surface ("sanitizing") and thereby preventing the infection of eggs by horizontal transmission of bacteria.

This opinion identifies and evaluates advantages and disadvantages, from a safety point of view, of using washing systems to sanitize table eggs (grade A).

Modern in-line egg washing procedures can normally be divided into three stages. The **pre-washing or wetting stage** is usually done using a gentle spray of warm water. The **washing process** typically involves rubbing the eggs with brushes and/or spraying them with jets of potable water containing chemicals. The final stage of the process, **rinsing**, aims to remove any loose debris that the egg has picked up during the main wash and also to remove the residues of any chemicals or other dissolved matter. These stages are followed by what may be referred to as post-washing treatments, such as drying and possibly oiling and/or cooling.

The major advantage of using washing systems for table (Grade A) eggs is the reduction of microbial load on the surface of "clean" eggs (sanitized eggs). Data regarding current egg washing practices indicates a bacterial reduction of 1 to 6 $\log_{10}$ units. However, sanitizing eggs will not prevent egg related diseases caused by microorganisms, such as *S.* Enteritidis, that are already present inside the egg. Table eggs sanitised by these means will contribute to a general hygienic improvement and a decrease in the potential for cross-contamination during food preparation.

The major disadvantage of egg washing is the potential damage to the physical barriers, such as the cuticle, which can occur during or after washing, for instance from incorrect operations, in particular washing eggs in cold water. Such damage may favour trans-shell contamination with bacteria and moisture loss and thereby increase the risk to consumers particularly if subsequent drying and storage conditions are sub-optimal. Whilst any shell damage should be seen as a disadvantage of washing, it should be balanced against the fact that washed eggs normally have considerably lower microbiological populations on the shell. Nonetheless, the aim must be to avoid, or at least minimise any such damage. No epidemiological data on the public health effect of egg washing is available.

There are also other options that can reduce the risks to consumers associated with washing of eggs. These include:

1. Preventing *Salmonella* spp. infection, especially *S.* Enteritidis, in primary layer production will reduce the occurrence of *Salmonella* spp. in eggs, especially on the surface of the eggs, and thereby reducing the risks associated with egg washing. If *Salmonella* spp. is not present, any risks associated with potential damage to the cuticle from washing, will be much lower compared with a situation where the birds may be infected with *Salmonella* spp.

2. The risks associated with egg washing can be reduced by the adoption of defined best washing practice procedures at all times. In countries where the washing of Class A eggs is permitted, the process is carried out using on-line systems whereby all eggs destined for Class A are treated. The process is undertaken immediately prior to grading and packing.

3. Prompt and thorough drying of eggs after washing and before packing is important to avoid mould growth and bacterial trans-shell penetration.

4. Oiling the cuticular surface of the egg which seals the shell pores can help to maintain the internal quality of eggs during storage and can thereby reduce the risk associated with washing.

5. Storage of eggs below 8°C could be an option to prevent growth of pathogenic bacteria such as *Salmonella* spp. present in the egg. However, after eggs have been refrigerated, they need to be kept in that state, mainly because a cold egg left out at room temperature can lead to condensation facilitating the growth of bacteria on the shell and probably ingress into the egg especially if the shell is damaged.

6. The use of UV-light either alone or in connection with washing can reduce bacterial load further. However, the reduction depends on the dose of UV used and on the protection of microorganism as a result of shadow as is the case in dirty eggs.

According to the information provided by Sweden, washed eggs had lower microbial counts on the shell surface than unwashed eggs and no movement of microbes from the shell to the content was reported following washing process. However, no data were provided regarding whether the particular Swedish washing process caused any damage to the shell cuticle. Moreover, specification of the maximum holding time for eggs prior to washing and of the maximum iron content for the water was not given. In Sweden, consumer preference is weighted in favour of washed eggs and the Swedish authorities point out that to ensure egg safety, the process must be conducted under the strictest rules with regard to operation of apparatus. "

The evaluation of advantages and disadvantages of egg washing need to be related to a particular system of washing. If well done, there are clear advantages to egg washing because of the reduced microbial load, but poor practices increase the risk. The greatest risk in relation to egg washing is penetration of the egg by *Salmonella* spp. Thus, in countries where the *Salmonella* prevalence in layers is very low, the risk of egg washing will also be lower. Taking into account the very low prevalence of *Salmonella* spp. in Swedish egg production, the risk associated with egg washing using the current system under strict rules is considered to be outweighed by the advantages of egg washing.

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LEGAL BACKGROUND

In accordance with Council Regulation (EEC) No 1907/90 on certain marketing standards for eggs[2], as last amended by Council Regulation (EC) 2052/2003[3], eggs are graded in packing centres by quality. Table eggs are normally grade A eggs.

A fresh egg of grade A has to be produced in a way that ensures it is fit for human consumption. It must comply with the minimum characteristics laid down in Article 5 of Commission Regulation (EEC) No 2295/2003 of 23 December 2003 introducing detailed rules for implementing Regulation (EEC) No 1907/90 on certain marketing standards for eggs[4]. In particular, its shell and cuticle must be normal, naturally clean and undamaged.

The washing of table eggs of class A is not permitted by Community legislation. In particular, it is stated that *"Grade 'A' eggs shall not be washed or cleaned by any other means before or after grading."*

Up to 31 December 2003, three classes were set down in Regulation (EEC) No 1907/90 as follows:

- class A or 'fresh eggs';
- class B or 'second quality or preserved eggs';
- class C or 'down-graded eggs intended for the food industry'.

The prohibition on the washing of class A eggs was already in force. As a consequence, before 31 December 2003, eggs which were washed had to be downgraded to class B eggs and marked as such. However, selling class B eggs as table eggs was possible.

As of 1 January 2004, Community legislation[5] provides for the merging of old class B and C eggs into a unique class B so that new class B eggs should not be sold as table eggs any longer but be destined for food industry use. This new legal situation implies that washed eggs should no longer be sold as table eggs.

Following the Commission report to the Council, a further amendment to Regulation 1907/90 was recently adopted by the Council to allow egg packing establishments, which on 1 June 2003 were approved by national authorities to wash table eggs, to continue this practice until 31 December 2006.

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2 OJ L 173, 6.7.1990, p. 5.
3 OJ L 305, 22.11.2003, p. 1.
4 OJ L 340, 24.12.2003, p. 16.
5 Council Regulation 1907/90 as amended by Regulation 5/2001.

State of play

Washing of eggs is rarely applied within the EU, except by a few packers in Sweden (10) and one packer in the Netherlands. This is in contrast to certain third countries such as the USA and, more recently in Japan where washing of eggs is commonly practised. In countries where egg washing is permitted, this practice is considered a fairly low risk operation.

In Sweden the washing of eggs has been practised for the past forty years. Swedish consumer attitude is to prefer washed eggs. This demand for washing is very strong from the catering sector, especially hospitals. More than 50% of table eggs are washed in Sweden.

The concern shown within the EU about allowing the practice of washing eggs arises first from the possibility of deterioration of the cuticle, which protects the egg against dehydration and offers a natural barrier to common microorganisms, and occasional pathogenic microorganisms, present in the flora that colonise the surface of an egg. This concern is also linked to the possible use of washing to cover up poor husbandry and hygiene standards on farms and in packing centres

On the other hand, the emergence of egg-associated *Salmonella* Enteritidis and other *Salmonella* spp. as significant causes of food poisoning has, together with the increase in non-caged egg production (floor or enriched cages production) where layers are more in contact with litter, manure and microorganisms living in the environment, increased the interest shown in technologies that might improve the microbiological safety of eggs.

Developments in Sweden

The Swedish authorities asked the European Commission to be allowed to continue to wash table eggs for their national market. To support their request, the Swedish authorities submitted an application giving information on industrial egg washing in Sweden as regards the authorities' supervision and control, washing methods and consumer attitudes towards washed eggs. Attached to this document is a report from the Swedish Institute for Food and Biotechnology comparing the quality of washed and unwashed eggs.

TERMS OF REFERENCE

The European Food Safety Authority is asked to:

- identify and evaluate the advantages and disadvantages of the washing of table eggs from a safety point of view;
- evaluate possible options (including post washing treatments) to reduce the risks for consumers associated with this practice;
- evaluate, in this context and on the basis of the elements provided by Sweden, the ability of the proposed Swedish process to provide safely washed eggs.

ASSESSMENT

1. INTRODUCTION

Laying hens are kept to produce eggs intended for human consumption. Two categories of egg can be identified, namely (i) shell eggs (*table eggs*) marketed for direct consumption or use in domestic preparation, and (ii) *egg products* comprising either separate products (yolk and albumen) or a mixture of these two components. Most of the latter products undergo thermal treatments (pasteurisation) or desiccation and are mainly intended for the industrial preparation of a variety of foods (pastries, dairy products, etc).

Concerning marketing standards of eggs, Commission Regulation (EEC) 2295/2003[6] define two grades (classes) of table eggs (A and B) according to different physical characteristics: (i) Grade (class) A eggs ("fresh eggs") should have a "normal, clean and undamaged" shell and cuticle; they will not be washed or cleaned before or after grading, and will be not chilled or treated for preservation. (ii) Grade (class) B eggs, i.e. eggs "which do not meet requirements applicable to eggs in grade A". Such eggs may only be used by the food or non-food industries.

Cleaning of eggs involves the use of water and subsequently detergents to clean the eggshell. In the EU, these eggs cannot be sold as "table eggs".

The surface of an egg can become contaminated with any microorganism that is excreted by the laying hen and contact with nesting material, dust, feedstuff, shipping and storage containers. Human beings and other animals may also be a source of shell contamination. Many foodborne pathogens or spoilage organisms can contaminate the internal contents or be present on the shell of eggs. The most important are *Micrococcus* spp., *Arthrobacter* spp., *Alcaligenes* spp., *Achromobacter* spp., *Pseudomonas* spp., *Escherichia coli, Salmonella* spp., *Yersinia enterocolitica* and *Listeria monocytogenes* (Board, 1966; Humphrey, 1994). Egg-associated infections are mainly caused by *S.* Enteritidis and shell eggs are considered the predominant source of human salmonellosis in Europe as well as many other countries worldwide (SCVPH, 2003). *S.* Enteritidis constitutes more than 50 % of all *Salmonella* spp. isolated from humans in European countries. (European Commission, 2003)

[6] OJ L 340, 24.12.2003.

The data on reported egg-borne infections are limited to *Salmonella* spp. (predominantly to *S*. Enteritidis and in very rare cases to other serovars) and *Staphylococcus aureus*. In cases where *S. aureus* was involved in egg-borne diseases, this was mostly the result of hygiene failures during handling of eggs in the kitchen. Therefore, this assessment only addresses contamination of eggs and egg contents with *Salmonella* spp.

1.1 EGG SHELL STRUCTURE

In its progress from the ovary to the cloaca, the yolk mass becomes enveloped in the viscous albumen, with its complement of structural and antibacterial proteins. In this sequential programme of events, the paired shell membranes, each comprising a protein core surrounded by a carbohydrate mantle, wind themselves around the egg white and in so doing begin to give the descending mass an egg shape. The inner surface of the membrane adjacent to the albumen is amorphous, while the outer surface of the membrane onto which the calcium salts seed, is chemically modified at specific sites to encourage the nucleation process.

The shell is a porous (12-20 µm in diameter) multilayered bioceramic. Working out from its inner surface, it is made up of a mammillary layer, cone layer, palisade layer, vertical crystal layer and cuticle (Figure 1 and 2). The morphological variations which occur within the shell have been the subject of numerous communications (Bain, 1990; Solomon, 1991) and their presence correlated with a variety of environmental and dietary influences. The last decade has witnessed a surge in interest with regard to the protein matrix, i.e. the scaffolding within the shell, which facilitates the elastic response when the egg is under load.

Figure 1. Schematic diagram of the egg,.

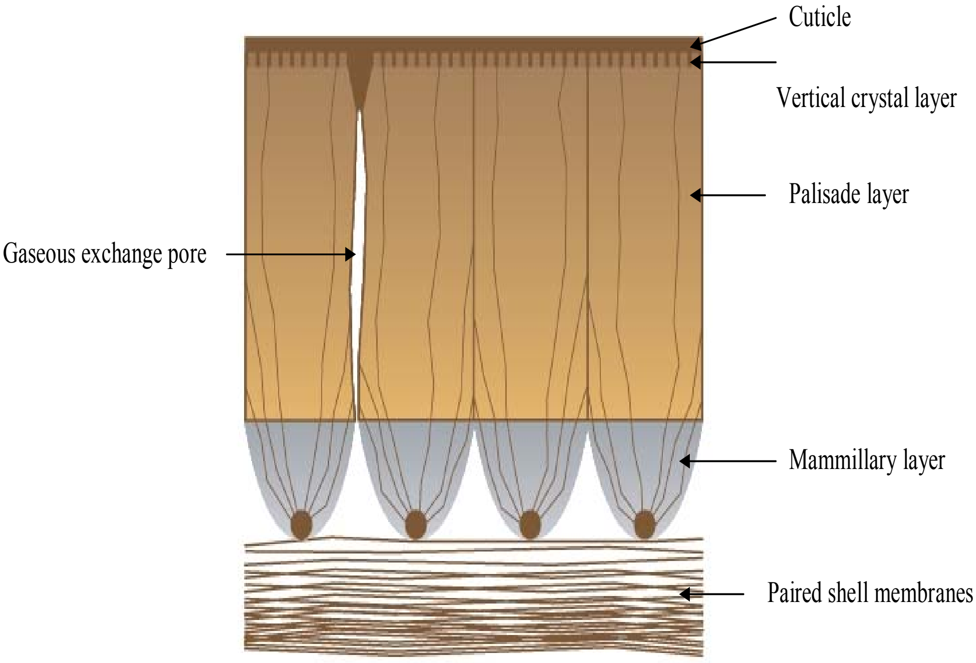
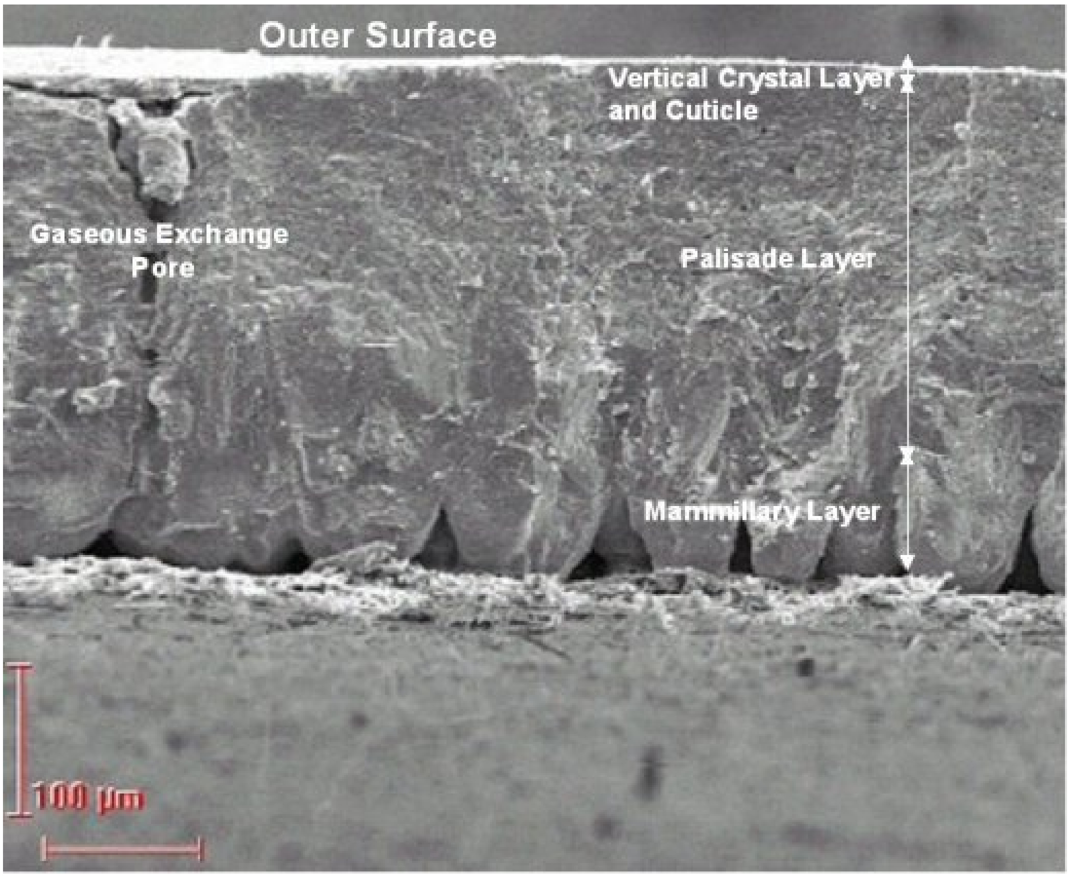


Figure 2. Electromicrograph of the egg shell including pore sizes (Bain and Solomon, University of Glasgow).



1.1.1. Shell Matrix Proteins

When the eggshell is decalcified, a delicate web remains. At ultra structural level it has a fibrous appearance interspersed with numerous vesicular holes. The distribution of the latter varies, both within the depth of the shell and with increasing bird age, thereby demonstrating changes in the gross morphology of this complex protein network. It is of oviductal origin with all regions distal to and including the magnum involved in the synthesis of the protein moiety. To date the following components have been isolated and identified using a variety of chromatographic techniques including anion exchange and gel filtration: ovocleidin, ovocalyxin, ovotransferrin, ovalbumin, osteopontin, lysozyme, clusterin (Hincke *et al.*, 2000). Several are of egg white origin, others like clusterin and osteopontin are ubiquitous, but the ovocleidins and ovocalyxins are specific to the shell gland pouch. The functions of the proteins are as diverse as their type. Thus, the egg white protein lysozyme is implicated in bacterial defence as is the shell gland specific protein ovocalyxin. Others proteins exert their effect in the process of mineralization and are responsible for the observed changes in the direction of crystal growth. Existing as they do, both within and between the calcite crystals, the proteins modulate crystal nucleation and growth and thereby influence the shape and strength of the final structure (Hincke *et al.*, 1995).

1.1.2. The Cuticle

The cuticle is a protein carbohydrate complex which is secreted in the shell gland pouch during the last hour of shell formation. It also contains a small amount of the crystal complex hydroxyapatite. The ability to synthesise cuticular material decreases with increasing bird age and so the presence of an even cuticular covering over the surface of the shell is fairly rare. The cuticle is not visible to the naked eye. Care must therefore be taken when handling the egg, since in the absence of the outer covering and the protective plugs it provides for the gas exchange pores which permeate all shells, the calcite complex is now vulnerable to the ingress of undesirable microorganisms from the surrounding environment.

1.2 MECHANISMS OF MICROBIAL CONTAMINATION

Bacterial infections of shell eggs can occur in two different ways: either vertically or horizontally. Of these, the first is mainly associated with *Salmonella* spp., especially *S.* Enteritidis.

1.2.1 Vertical transmission

In this opinion, vertical transmission is considered to be a direct deposition of *Salmonella* spp. into the follicles or yolk, while still present and/or attached to the ovary. This is known as the trans-ovarian route. Vertical transmission occurs when a hen is systemically infected with *Salmonella* spp. through an oral infection. Many studies have shown that poultry can become infected after oral inoculation without showing clinical signs. However, after intravenous or intramuscular infection, birds may become ill (Forsythe *et al*., 1967, Bolder *et al.*, 1991, Desmidt *et al*., 1997). A small number of bacterial types of economic and zoonotic significance to the poultry industry are transmitted vertically, amongst the *Salmonella* spp., these include *S.* Gallinarum, *S.* Pullorum, *S.* Enteritidis, *S.* Typhimurium and some strains of *S. arizonae*. Of these, *S.* Gallinarum and *S.* Pullorum produce clinical disease within the reticuloendothelial system. Vertical transmission of the other *Salmonella* types is more unusual, although evidence shows that invasion by *S.* Enteritidis and *S.* Typhimurium can lead to translocalisation of these microorganisms in the ovary and oviduct.

Gast and Holt (2001) found only occasional *S.* Enteritidis infections of the yolk itself and more frequent presence of *S.* Enteritidis on the yolk membrane. Barrow *et al*. (1991) found ovaries infected with *Salmonella* spp., but could not isolate this bacterium from the egg contents. Following systemic *Salmonella* infection, sequential faecal shedding of these bacteria can occur with potential risk to the forming egg. Bolder *et al*. (2002) infected broilers intramuscularly and found caecal colonization and faecal *Salmonella* shedding.

1.2.2 Horizontal transmission

In this opinion, two types of horizontal transmission will be considered: before (internal) and after (external) shell formation. This covers the whole area from detachment of mature follicles, to the point where the egg is collected and further to include trans-shell penetration.

During the journey of the ovum from the ovary to the cloaca there are many possibilities for infection since bacteria from the cloacal area can enter the oviduct and move towards the upper part, the magnum. Here bacteria can be incorporated into the albumen or even directly on the yolk membrane. This can be illustrated with the experiments of Reiber *et al.* (1995), who inoculated *Salmonella* spp. contaminated sperm, and occasionally isolated these bacteria from egg contents.

The egg passes through a highly contaminated cloacal area at the moment of lay. This is often illustrated by visible faecal contamination on the shell. While being wet and entering an environment with a temperature of approximately 20ºC below the hen's body temperature, the egg will cool immediately. The egg contents will contract and a negative pressure establishes inside the egg, thereby moving contaminants through the shell (Padron, 1990). This contamination will deposit at the shell membranes, and pose a future threat to the egg. Grijspeerdt *et al.* (2004) show in a growth model how such an infection can develop inside an egg.

Jones *et al*. (2004b) collected freshly laid eggs at five different hen ages and inoculated them with *S.* Enteritidis and/or *Pseudomonas fluorescens* directly after laying. After storage for up to five weeks at room temperature, egg contents and shell contamination levels of both organisms increased with storage time. This phenomenon was more pronounced with eggs from older hens than from younger hens.

The surface of an egg can become contaminated with any microorganism that is excreted by the laying hen. In addition, contact with nesting material, dust, feedstuff, shipping and storage containers, human beings and other animals may be a source of shell contamination. The likelihood of trans-shell penetration increases with the length of time that the eggs are in contact with contaminating material. Sauter and Petersen (1974) observed that shell quality (specific gravity) influenced the penetration rate of a wide variety of *Salmonella* spp. through the shell.

1.3 GENERAL DEFENCE MECHANISMS

In a well structured shell, the cuticle and the calcite complex of the shell itself provides a competent barrier to horizontal bacterial contamination. The shell provides both a mechanical and chemical barrier to microorganisms through the gas exchange pores, blocked by cuticular plugs and the presence of antibacterial proteins within the shell matrix. If the shell is breached, then invading bacteria must progress through the web of membrane fibres before they reach the albumen mass. These fibres too have a complement of antibacterial proteins. Once in the egg white, bacteria are faced with a series of very effective defence mechanisms. Egg white is turgid and this viscosity will in itself inhibit movement. Albumen provides no nutrition for microorganisms and so the latter are held in suspension within the albumen sac where they are rendered inactive by the presence of a third mechanism of defence - the antibacterial proteins. These antibacterial proteins include ovo-transferrin, lyzozyme and avidin.

If the shell is properly constructed in terms of shell thickness and the presence of an adequate cuticular layer enveloping the multilayered shell, these physical attributes, together with the inherent compliment of antibacterial proteins, will minimise bacterial migration to the egg contents. The shell is a porous structure, with pore numbers varying according to egg size and location. Not all pores penetrate the entire depth of the shell. These gas exchange mechanisms originate from the inner surface of the forming shell and many end blindly within the palisade columns. Those that communicate with the shell surface represent portals of entry for a variety of microorganisms and other elements from the surrounding environment. In theory, they should be blocked by cuticular plugs, but the pressure put on current laying flocks to produce in excess of 300 eggs per year has witnessed acceleration in egg formation with the consequence that cuticle formation has been compromised. Despite their potential to assist in bacterial entry, pores do not represent the prime route of transfer. According to Nascimento (1992), shell imperfections are more significant in this respect. In a series of experiments designed to monitor the transfer of gold tagged *S.* Enteritidis across the shell wall, the author observed microorganisms at areas of structural weakness within the fully formed shell. Once through the shell, any invading microorganism must breach the barrier formed by the shell membranes. The latter possess antibacterial properties, but they are a temporary barrier when faced with a heavy bacterial challenge.

2 TOR 1. IDENTIFY AND EVALUATE THE ADVANTAGES AND DISADVANTAGES OF THE WASHING OF TABLE EGGS FROM A SAFETY POINT OF VIEW

2.1 DIFFERENT WASHING PRACTICES (Annex 1)

These practices have been mainly developed to clean dirty eggs (grade B).

Modern in-line egg washing procedure can normally be divided into three stages, namely pre-wash (or wetting), and wash and rinse. These stages are followed by what may be referred to as post-washing treatments such as drying and possibly oiling.

The ***pre-washing*** or wetting stage is designed to soften debris such as faecal material and egg varnish on the shell. This is usually done using a gentle spray of warm water. To achieve maximum benefit from the pre-wash, there should be, if possible, a short interval before the main wash begins to allow water to penetrate the soil material. In commercial practice, this interval is often minimal.

The ***washing*** process typically involves rubbing the eggs with brushes and/or spraying them with jets of water.

The final stage of the process, ***rinsing,*** aims to remove any loose debris that the egg has picked up during the main wash and also to remove the residues of any chemicals or other dissolved matter.

Throughout each of these stages, the conveyor on which the eggs are moved incorporate rollers. The eggs therefore rotate so that the entire shell surface is presented to the brushes or water jets.

The critical issues are:

- Eggs are washed as soon as possible after they are laid and the temperature of the wash water must exceed the temperature of the eggs.
- Dirty eggs and those with weak or broken shells are removed before washing begins.
- The water itself is of potable quality with a low content of iron and the pH of the water is controlled.
- Appropriate sanitising chemicals are used and these must leave no residues and have no significant adverse effects upon the cuticle.

Commercial egg washing systems are designed and operated so that these requirements are met at all times. A key feature is to improve machines to avoid damage of the shell. Since failure to do this may mean that eggs are more vulnerable to microbial invasion and spoilage, the machines have to incorporate appropriate monitoring and failsafe devices.

In countries where the washing of Class A eggs is permitted, the process is carried out using in-line systems whereby all eggs destined for Class A are treated. The process is undertaken immediately prior to grading and packing.

2.2 MICROBIOLOGICAL EFFECTS OF EGG WASHING

Discussions on the hygienic effects of egg washing have a long history and are linked, among other studies, to reports of increased rates of spoilage for eggs that were washed under less than optimal conditions (Brooks, 1951). Early studies on the quality of stored eggs frequently showed that washing increased the probability of spoilage and for that reason, cleaning eggs by washing was once widely condemned. However, subsequent studies highlighted the factors responsible. Moats (1978) identified these as a) washing in water colder than the eggs, b) washing in water with high bacterial counts c) washing in water containing appreciable soluble iron and d) washing in machines with surfaces contaminated by bacteria. Modern egg washing practices must seek to address each of these issues.

Physical damage to the egg surface caused by the use of some chemicals and sanitizers can occur (Kim and Slavik, 1996; Wang and Slavik, 1998; Favier *et al*., 2000b). A number of publications indicated that the historical practices of egg washing resulted in an increase of internal bacterial contamination (Haines and Moran, 1940; Lorenz and Starr, 1952; Brant and Starr, 1962), whereas recent studies testing more modern egg washing procedures indicate the opposite (Lucore *et al*., 1997; Hutchison *et al*., 2003 and 2004).

The key variables of the washing process are outlined below.

2.2.1 . Water temperature

Water temperature has generally been regarded as the most important aspect of safe and effective egg washing. A fundamental requirement is that the temperature of the water should exceed the temperature of the eggs being washed.

Haines and Moran (1940) were possibly the first to observe that when eggs are placed in a cooler bacterial suspension, a pressure gradient is set up which draws bacteria through the shell into the interior. Conversely, if the bacterial suspension is warmer than the egg, a positive hydrostatic pressure is created which minimises the movement of bacteria into the egg. This principle is fundamental to understanding how to wash eggs in such a way that the risk of bacteria moving through the shell is minimised.

Brant and Starr (1962) concluded that the temperature of the wash water should be at least 11°C higher than the egg temperature. In practice, the water temperature often increases as eggs progress through the washing process, with the temperature of the pre-wash water being the lowest. The temperature of the final rinse water should always be slightly higher than the temperature of the wash water. In addition to minimising the risk of bacterial invasion, this is also considered to aid the subsequent drying process.

Studies have shown that increasing the water temperature has beneficial effects upon the inactivation of microbes. Leclair *et al*. (1994) studied the effects of wash water temperature in the range 38°C to 46°C on the inactivation of *S.* Typhimurium and *Listeria monocytogenes*. Both pathogens were significantly affected (>4-log reduction) by increasing the wash water temperature. Similarly, Bartlett *et al*. (1993) reported that in the presence of wash chemicals, there was an inverse correlation ($r^2>0.65$) between the temperature of egg wash water and the total aerobic counts that the water contained. Bartlett's work showed that the control of temperature and pH alone was insufficient to ensure the quality of wash water. Based on a recommended temperature of >40°C and pH >10, they recommended the use of a chlorinated alkaline detergent with a minimum total available chlorine concentration of 0.45mg/l.

In commercial practice, the temperature of the eggs will vary according to the temperature of the storage environment. Eggs that are conveyed directly from the laying house to an in-line washing machine are likely to be the warmest. It is important therefore that this temperature is considered when setting up the egg washing machine so that negative pressure differentials are avoided.

An additional consideration however, is that as wash water temperature rises, there is an increased risk of cuticle damage and thermal cracking. For this reason Wesley and Beane (1967) recommended that wash water temperatures greater than 45°C should be avoided.

Washing in warm water will however increase the temperature of the eggs themselves and this can have implications for egg quality during storage. However, work by Lucore *et al.* (1997) has questioned the traditionally held view that washing in cold water represents a high risk. They used a spray wash system to compare the effects of three wash water temperatures (15.5°C, 32.2°C and 48.9°C) upon internal and external shell surface bacterial counts. The treatments used were shorter in duration than would normally be applied in commercial practice, namely ten seconds for washing and three seconds for rinsing. Under these conditions, they concluded that spray washing of eggs at the lowest temperature did not increase internal shell bacterial counts.

Hutchison *et al*. (2004) demonstrated that for the spray-jet washer the temperature of the water was the most important parameter for inactivating microorganisms on the egg shell and for preventing the ingress of *Salmonella* spp. entry into the egg. Regarding the other washing machine parameters tested, the age of laying birds and the use of a chlorine-based wash sanitizer and of rinse sanitizer had no significant additional effects. Kinner and Moats (1981) reported that the temperature range used for water in egg washing machines was not lethal to most types of bacteria at neutral pH, but the use of alkaline sanitisers increases the pH of the water to around 10-11 which is unfavourable to the growth of most bacteria. They concluded that the pH and water temperature conditions commonly used in commercial egg washing should control build up of bacteria without the use of other bactericidal chemicals.

2.2.2 . Washing Time

Brant and Starr (1962) reported that provided the temperature of the wash water was at least 11°C higher than the egg temperature, treatment time was relatively unimportant in terms of bacterial uptake into the egg. They concluded that the treatment time should be determined by considerations of shell cleanliness rather than by the danger of spoilage. Hutchison *et al.* (2004) also found that washing treatment time had no effect upon surface levels of contaminants or on the incidence of *Salmonella* spp. in the egg contents.

2.2.3 . Storage Temperature and Time Prior to Washing

Wang and Slavik (1998) investigated bacterial penetration of eggs that had been stored for different lengths of time and at different temperatures before being washed under conditions similar to those used commercially. The study found that the two different storage temperatures investigated (4°C and 23°C), did not significantly affect the penetration of eggs by *Salmonella* spp. within the 0 to 21 day storage periods used. However, when eggs were subsequently washed, a correlation was found between the age of egg and penetration of egg contents by *Salmonella* spp. In general, the longer the storage time prior to washing, the higher the levels of penetration by the pathogen.

It is generally accepted that if eggs are to be washed, the process should take place as soon as possible after the egg is laid. Eggs are normally washed, at the latest, within 7 days following the laying date.

2.2.4 . Water quality, mineral content and pH.

Egg wash water used for supplying the machine, must be of a standard equivalent to potable water. Soft water with low calcium content is ideal because this reduces the rate of calcification which is always a problem within the machine due to calcium release from shell fragments. Of great importance is the level of iron in the water. The role of iron in accelerating development of rots has been clearly established (Garibaldi and Bayne, 1960 and 1962). In the context of egg washing, the risk is from high soluble iron content in the wash water. Under adverse egg washing conditions, water could be drawn into the egg and the iron would severely reduce the effectiveness of the in-built defence mechanisms within the albumen. Egg washing legislation, in countries where it is permitted, takes account of the potential risk of iron (particularly in water from wells). The normal recommendation is that iron content should be regularly tested and should not exceed a maximum of 2 ppm in wash water. Moats (1978**)** summarizes the possible effects resulting from the presence of iron in water for egg washing. The presence of iron in wash water may inactivate certain sanitizers used during washing and may also accelerate growth of certain spoilage microorganisms, such as *Pseudomonas* spp. and other Gram negative bacteria. Iron may also enable *Pseudomonas* spp. to penetrate the shell. When iron containing water is drawn into the egg as a consequence of bad operational practice, it may bind to conalbumin and therefore eliminate microbial growth. Growth of bacteria could be accelerated by the presence of iron or manganese.

Egg washing water pH is normally high (around 9 to 11), due to the chemicals used for washing. However, successful trials have also been carried out using acidic chemicals such as peracetic acid, where the level fell to pH 5. Bartlett *et al.* (1993) reported that there is a strong relationship between high pH (greater than 10.5) and low counts of total aerobic bacteria in wash water sampled from commercial facilities. Jones *et al.* (1995) isolated *S.* Heidelberg from the shells of eggs washed under commercial conditions when the pH of the wash water was allowed to fall below pH 10.2. Furthermore, pH-dependent reductions in the levels of *S.* Typhimurium and *L. monocytogenes* were reported by Leclair *et al*. (1994).

2.2.5 Wash chemicals

In a review of egg washing, Moats (1978) concluded that eggs washed with a sanitising chemical in the wash water invariably spoiled fewer eggs than when eggs were washed only in water. However, bacteria that had penetrated into the pores of the shells were protected from the antimicrobial action of the sanitising chemicals. Moats further concluded that reports on the effectiveness of various sanitizers are conflicting. This is consistent with the views of Nield (1992) who observed that in commercial practice, the success of a particular type of sanitiser is very dependent on the quality of the water being used. Consequently, a sanitiser that worked well in one location may not be as effective elsewhere. However, studies such as those of Bartlett *et al*. (1993) have concluded that there is a strong relationship between effective bacterial kill and the total chlorine present in wash water.

More specifically, Favier *et al*. (2000a) compared how survival of *Yersinia enterocolitica* and total aerobic counts were influenced by washing using hypochlorite, lactic or acetic acid. Although chlorine, at concentrations of 200 ppm was far more effective at reducing aerobic counts on the shell surface, *Y. enterocolitica* was equally sensitive to chlorine and organic acid.

Soljour *et al*. (2004) evaluated the efficacy of three commercial cleaning and/or sanitizing compounds (sodium carbonate, sodium hypochlorite, and potassium hydroxide) for bactericidal inactivation at pH values of 10, 11, and 12 against various concentrations (10^2, 10^4, or 10^6 cfu/ml) of *S.* Enteritidis inoculated onto the egg shell surface. Efficacy of these chemical agents was also assessed against *S.* Enteritidis in aqueous suspension. None of the chemicals, when applied at the manufacturer's recommended concentrations (sodium carbonate, 36 ppm; other treatments, 200 ppm), eliminated *S.* Enteritidis from eggshells artificially contaminated with the highest bacterial concentrations (10^4 or 10^6 cfu/ml). Concentrations at least 5 to 20 times greater than those recommended were needed to kill the bacteria on egg surfaces. However, at or slightly above the manufacturer's recommended concentrations, all three formulations were effective against *S.* Enteritidis in aqueous suspension (10^8 cfu/ml) or on eggshells contaminated with 10^2 cfu/ml. For both shell and suspension assays, inactivation of *S.* Enteritidis occurred at lower concentrations at pH 12 than at pH 11 and pH 10. Contact time between chemicals and *S.* Enteritidis apparently influenced bacterial inactivation. Extended contact times (2 to 10 min) reduced the minimum chemical concentrations necessary to inactivate the bacteria. However, neither pH nor contact time influenced *S.* Enteritidis inactivation when the initial bacterial numbers on eggshells were high.

Most of the chemicals used in the egg washing process are supplied by the machine manufacturers. All of the chemicals used must be compatible each other. In current commercial practice, chlorine and quaternary ammonium compounds are commonly used. Foaming may be a problem with some detergents and so anti-foaming agents must be included.

Chemicals that are effective in reducing the bacterial load on egg shells may however damage the cuticle or shell, rendering the egg more vulnerable to subsequent microbiological invasion. Eggs produced by older hens may generally be most at risk as a result of inferior initial shell quality. Wang and Slavik (1998) reported that washing with sodium carbonate severely damaged the cuticle while washing eggs in 100 ppm sodium hypochlorite did not significantly alter it. Washing with quaternary ammonium also appeared to preserve the cuticle but residues of the wash compound remained on the shell after washing and drying.

Finally, Hutchison *et al*. (2004) investigated the effects of spray jet washing under various processing conditions on shell surface counts of *Salmonella* spp. and the presence of bacteria in eggs. Experiments used eggs that were contaminated with *S.* Enteritidis PT4 or *S.* Typhimurium DT104 before cuticle hardening. Washing of contaminated eggs under optimum conditions resulted in more than 5 $\log_{10}$ reduction of *Salmonella* spp. counts from the shell surface. *Salmonella* spp. was not isolated from the yolk or albumen of any egg washed using the optimal protocol, suggesting that when properly controlled, egg washing did not cause *Salmonella* spp. to enter the eggs. However, contamination did arise if strict control was not maintained over the wash and rinse water temperature. Both *S.* Enteritidis and *S.* Typhimurium were shown to enter the egg when the water temperature was lowered from 44-48^{o}C to 25-27^{o}C. Other washing parameters that were investigated did not markedly affect the entry into the eggs, but influenced shell surface kill levels to varying degrees.

2.3 ADVANTAGES AND DISADVANTAGES OF EGG WASHING

This chapter identifies and evaluates "advantages" and "disadvantages" of sanitising table eggs from a safety point of view i.e. "decreasing" the number of bacteria present on the surface of "clean" eggs.

The advantages and disadvantages of egg washing have been debated for many years. There is no doubt that early attempts at washing eggs were unsuccessful and a review carried out in the UK in 1951 concluded that the effects of egg washing were unpredictable, and frequently disastrous (Brooks, 1951). Rots and other egg quality problems were frequently reported in washed eggs after storage. It is now apparent that the egg washing systems in use at the time were unsophisticated and that there was little understanding of the safeguards and requirements for successful egg washing. Nevertheless, these early findings demonstrate that egg washing can be harmful if it is done incorrectly and this remains the case to the present day.

2.3.1 Advantages

The major advantage of washing is that it reduces the microbial load on the shell surface, thereby minimizing the risk associated with the presence of foodborne pathogens, especially *Salmonella* spp.

It is evident from numerous studies that washing reduces the microbial populations on the shell surface. Even visibly clean eggs typically have a substantial microbial load on the shell surface, with eggs laid in nest-boxes generally showing higher levels than those laid in conventional cages. Whilst good management and husbandry practices help to reduce microbial populations on the shell, tests show that further reductions occur after washing. It is clear that in some countries where washing is practised, it is seen as a means of improving microbial quality and of reducing the risks of infection of the internal egg. An additional advantage of lower microbial populations is the reduced risk of cross contamination to other foods. This could arise from direct contact between eggs and other foods during storage or use, or via the hands of food handlers in the kitchen.

Consequently, egg washing reduces the risk of contamination of the egg content, provided that the shell itself is not damaged.

2.3.2 Disadvantages

The major disadvantage of egg washing is the potential damage to the physical barriers, such as to the cuticle that may favour trans-shell contamination with bacteria and moisture loss and thereby increasing the risk to the consumers. The greatest risk in relation to egg washing is penetration of the egg by *Salmonella* spp. that may be present on the surface of the shell before washing. Thus, if the *Salmonella* prevalence in layers is low, the disadvantage and risk of egg washing will also be relatively lower.

Research studies have shown that some washing systems can cause damage to the shell. For example, some brush washing systems have been shown to cause damage to shell structure and particularly to the cuticle. Very high pressure water jets may also cause damage. Eggs from older birds may be more vulnerable to damage.

Assessment of commercial practices has frequently found that drying facilities are inadequate. If the shells are still moist when the eggs are packed, it would be reasonable to assume that there is an increased risk of subsequent problems of mould growth and other microbiological problems during storage.

2.3.3 Balancing advantages and disadvantages

Any evaluation of the advantages or disadvantages of egg washing needs to be related to a particular system of washing. If well done, there are clear advantages to egg washing, although poor practices increase the risk.

The greatest risk in relation to egg washing is the penetration of the egg by *Salmonella* spp. Preventing *Salmonella* spp. infection, especially *S.* Enteritidis, in primary layer production will reduce the occurrence of *Salmonella* spp. in eggs, especially on the surface of the eggs, and thereby reduce the risks associated with egg washing. Thus, if the *Salmonella* prevalence in layers is very low, the disadvantage and risk of egg washing will also be relatively lower.

Large scale, in-line egg washing machines were developed in the USA and the basic principles remain largely unchanged ever since. If required, egg washing machines can now incorporate comprehensive control systems which ensure that key operating parameters (e.g., water temperature, pH, detergent levels) are constantly met. This is important, given that the risks associated with egg washing are often due to a failure to control one or more of these parameters.

The full advantages of egg washing can only be obtained if all eggs are visually examined prior to washing and unsuitable eggs are removed. In existing egg packing centres, the incorporation of egg washing facilities may cause practical difficulties since a dry environment is currently maintained. It would be necessary to ensure that a separate room was provided for washing and that suitable drainage facilities could be provided.

3 TOR 2. EVALUATE POSSIBLE OPTIONS (INCLUDING POST WASHING TREATMENTS) TO REDUCE THE RISKS FOR CONSUMERS ASSOCIATED WITH THIS PRACTICE

The key factors required for successful egg washing and “sanitizing” are now understood and these form a framework for legislation and codes of practice in countries where egg washing is permitted. The risks associated with egg washing can be reduced by the adoption of defined best practice procedures at all times, covering: the supply and pre-inspection of table eggs to be washed, the pre-washing step, the main wash, the final rinse, and the drying and the storage after washing.

In the UK, a “blueprint” for egg washing was drawn up, giving some options to control the risks of bacterial contamination of the products (Annex 2). They are mainly:

- Washing eggs as soon as possible after laying (ideally less than 48 hours and definitely less than 7 days).

- Keeping eggs under clean and dry conditions and below 20°C, before washing, if necessary.

- Egg washing should be incorporated into an overall documented HACCP system.

- All water used should be of potable quality, containing iron and soft, and the temperature should be controlled during the whole process.

- Chemicals should be incorporated into the wash solutions if, under the conditions they are being used, they effectively remove microorganisms from the egg shell and do not damage the egg shell or its cuticle

- Eggs must be completely dried immediately after being rinsed.

3.1 POST WASHING TREATMENTS

3.1.1 Egg Drying

After eggs have been washed, they must be promptly and thoroughly dried prior to packing. If eggs are still wet when they are packed (particularly if packing is in sealed units), then there is an increased risk of mould growth. Bacteria may also be drawn into the egg through the damp shell as it cools.

To maintain the necessary throughput speed, eggs must be dried rapidly. They normally spend around 30 seconds in the drying sections of commercial machines and therefore the process has to be carefully designed and operated. In most systems, drying is achieved by high speed air which causes water to evaporate from the shell surface. The air can be supplied either in large volumes or as fine, high pressure jets which are carefully directed in order to 'cut' the water from the shell surface as the egg revolves. The drying process may also be aided if the air is warmed and/or de-humidified. The temperature of the egg shell is also important and the use of high water temperatures for the rinse stage is consistent with the requirements for effective drying.

Whilst the eggs are generally conveyed on rollers as they move through the drying process, some machines temporarily stop the rotation process so that the water can drain to the underside of the egg. The egg is then gently 'wiped' using soft brushes, which are kept dry by the gentle movement of air through them. Manufacturers of such systems claim that such brushes greatly aid the washing process although concerns have been raised about the potential for re-contamination of the egg shells because of the direct contact of the brushes.

Assessments of commercial egg washing systems have frequently concluded that the drying procedures are inadequate, since some or all of the eggs are not visibly dry at the time of packing. This has generally been due to shortcomings, either in design or in maintenance procedures. Neither of these problems is insurmountable and the fact that other sites can properly dry eggs illustrates that this need not be a problem.

3.1.2 Oiling

As soon as the egg is laid, carbon dioxide and moisture begin to escape through the shell pores. This causes a gradual increase in pH as eggs get older and this is accompanied by thinning of the thick albumen. At the same time, the vitalline membrane becomes weaker and the egg loses weight due to the loss of moisture.

Oiling eggs is intended to seal the shell pores, thereby reducing the rate of internal quality decline. It was first adopted to facilitate the long-term storage of eggs when production was seasonal, but it also impedes the movement of microbes through the shell. In the EU, oiling is not permitted for Class A eggs, but when machine washing of eggs began in other countries, oiling became commonplace since it was seen as a means of replacing cuticle lost during the washing process. In recent years however, oiling of eggs after washing has become less frequent since storage times have become shorter and there has been increased emphasis on storage temperature control.

Where egg oiling is practised, it is carried out immediately after drying and whilst the egg is still rotating on roller conveyors. A fine spray mist is applied, to ensure that all the surface of the egg shell is covered. For successful oiling, the surface of the egg must be entirely free of moisture (Hinton, 1968). Mineral oils are normally used in commercial practice although studies have also demonstrated the successful use of silicone fluids (Knight *et al.,* 1972).

Oiling of eggs helps to maintain the internal quality of eggs during storage. Sabrani and Payne (1978) assessed the effects of 24 days storage at 28°C on naturally clean (unwashed) eggs. They showed that oiling (using linseed oil) slowed the rate of decline of albumen quality and markedly decreased the weight loss of eggs during this period. Tests carried out in the early 1980s have assessed the effects of washing and oiling on albumen quality (Haugh Units) after 28 days of storage. Using commercial egg washing and oiling machinery, they compared eggs that had been washed and oiled with eggs that had been washed only. A control group of unwashed eggs was also tested. At the end of the storage period, quality was maintained best in eggs that had been both washed and oiled. Unwashed eggs were superior to those that had been washed but not oiled.

The beneficial effects of oiling are likely to vary, depending upon the nature and strength of the egg washing process. The aim must be to develop egg washing machines and practices that cause minimal (or no) damage to the cuticle and therefore obviate the need for oiling.

3.1.3 **Storage conditions**

In the EU, "grade A eggs should not be treated for preservation or chilled in premises or plants where the temperature is artificially maintained at less than 5°C." (E.C Regulation 2295/2003). Nevertheless, refrigeration of eggs can be a tool to control *Salmonella* spp. and in particular, the presence of *S.* Enteritidis in the yolk. For example, *Salmonella* spp. was not able to grow in the yolk of eggs stored at 8°C (Humphrey, 1990). In this manner, storage of eggs below 8°C could be an option to prevent growth of pathogenic bacteria such as *Salmonella* spp. present in the egg content not only because a vertical transmission, but also after penetration through the shell.

However, once eggs have been refrigerated, they need to be kept in that state, mainly because a cold egg left out at room temperature can lead to condensation facilitating the growth of bacteria on the shell and probably ingress into the egg, especially if the shell is damaged.

3.2 ALTERNATIVE PROCEDURES

3.2.1 . Ultraviolet light treatment

Some commercial egg packing centres now use ultraviolet light treatment in order to further reduce microbial populations on the unwashed egg shell. However, few results are available at present. So far, only introductory experiments with this decontamination technique have been carried out.

UV-C has a strong antimicrobial effect and UV-C tubes are now available with a high output capacity (up to 80 watt). This will reduce the UV-exposure time of eggs to a fraction of second, thus making industrial application possible.

Favier *et al*. (2001) observed a dose dependent effect of UV-treatment of unwashed eggs. Using a dose of 1.2 mJ/cm^2, an inactivation of the numbers of mesophilic aerobic bacteria present on egg shell of 1 log_{10} units was observed. Using a dose of 11 mJ/cm^2, a reduction of about 2.5 log_{10} units was observed. Identical results were obtained after treatment of shells which were artificially contaminated with *Yersinia enterocolitica*.

In a recent study by De Reu *et al*. (2005), UV-light (wavelength 253.7nm, 10 mW/cm^2) was used to decontaminate un-inoculated eggs and eggs inoculated artificially with *Escherichia coli*. It was found that with a dose of 47 mJ/cm^2, the natural bacterial load of clean eggs was reduced by about 1 log_{10}. However, when dirty eggs were used no significant reduction was obtained. The numbers of *E. coli* present on eggs after artificial inoculation were reduced by 3 log_{10} and 4 log_{10} units at a dose of 47 mJ/cm^2 and 188 mJ/cm^2 respectively.

The results shown above demonstrate the potential use of UV-light in the decontamination of eggs. They also demonstrate that the microbial reduction depends on the dose of UV used and on the protection of microorganisms by shadow as is the case in dirty eggs.

This treatment could be used in conjunction with washing procedures.

3.2.2 Use of electrolyzed oxidizing water as washing water.

A new development in sanitising surfaces is the use of electrolyzed oxidizing water. Bialka *et al*. (2004) were the first to test the effect of electrolyzed oxidizing (EO) water for egg shell decontamination using *Salmonella* Enteritidis and *Escherichia coli* K12 on artificially inoculated shell eggs. For the *in vitro* study, eggs were soaked in alkaline EO water followed by soaking in acidic EO water at various temperatures and times. Treated eggs showed a reduction in population between 0.6 and 2.6 log_{10} cfu/g of shell for *S.* Enteritidis and between 0.9 and 2.6 log_{10} for *E. coli* K12. Log_{10} reductions of 1.7 and 2.0

for *S.* Enteritidis and *E. coli* K12, respectively, were observed for typical commercial detergent-sanitizer treatments.

In a subsequent pilot-scale study, both the alkaline fraction and the acidic fraction of EO water were compared with detergent-sanitizer treatment using *E. coli* K12. Log_{10} reductions of $\geq$ 2.98 and $\geq$ 2.91 were found using the EO water treatment and the detergent-sanitizer treatments, respectively (Bialka *et al*., 2004).

4 TOR 3. EVALUATE, IN THIS CONTEXT AND ON THE BASIS OF THE ELEMENTS PROVIDED BY SWEDEN, THE ABILITY OF THE PROPOSED SWEDISH PROCESS TO PROVIDE SAFELY WASHED EGGS.

According to the information provided, consumer preference is weighted in favour of washed eggs and the Swedish authorities rightly point out that to ensure egg safety, the process must be conducted under the strictest rules with regard to operation of apparatus. The primary concern is *Salmonella* spp., but of course this is not the only bacterial species to colonise the shell surface. The Swedish data also appears to derive from one stage in the laying cycle of the bird. In their investigation, eggs were washed in a fine water spray at high pressure, and gently brushed for 45 seconds at a temperature of 41°C. This modern methodology has the greatest advantage since contact with the shell surface is minimised, nevertheless it is not without risk.

4.1 PROCEDURES USED IN COMMERCIAL EGG WASHING

The standards adopted in Sweden for egg washing, as set out in the National Food Administration's Inspection Manual for Egg Packing Centres, are broadly similar to those in place in the USA. However, in Sweden they do not appear to include a specification for iron content in the water. In addition, in Sweden the temperature of the water must exceed the temperature of the egg by at least 15°C, whilst in the USA the comparable figure is 11°C. Swedish legislation states that rinsing water must not be recycled other than as wash water, but there does not seem to be any equivalent requirement in the USA.

4.2 SCIENTIFIC DATA PRESENTED

A study entitled 'Comparison of qualities of washed and unwashed eggs' carried out at the Swedish Institute for Food and Biotechnology has been submitted for consideration as regards the benefits of washing eggs.

This was a comparatively small study comparing the quality of eggs washed using a standard commercial method with unwashed eggs. The findings are broadly as expected and similar to those reported elsewhere. Washed eggs were found to be visibly cleaner and to have lower microbial counts on the shell surface than unwashed eggs. No movement of microbes from the shell to the contents was reported following washing. Again, this is consistent with other reports which have drawn similar conclusions, so long as normal best practices are followed during the washing process. A concern has always been the degree to which the risks increase if eggs are washed using inappropriate systems.

4.3 Ability of the proposed Swedish process to provide safely washed eggs

Washing of eggs is an established practice within certain egg packing centres in Sweden and is regulated and monitored by the National Food Administration. An inspection manual has been prepared for egg packing centres which sets standards for egg washing and these are broadly similar to those adopted by other countries where washing of eggs is permitted. However, consideration should be given within these standards to specifying a maximum holding time for eggs prior to washing. This would ensure that eggs are washed promptly and would therefore reduce one potential risk factor. In addition, consideration should be given to specifying maximum iron content for the water.

Given the long history of washing in Sweden, using similar systems and given the lack of evidence of microbiological problems in washed eggs, it would appear that the risk associated with current commercial practices in this country is low. The study carried out by the Swedish Institute for Food and Biotechnology did not include an assessment of cuticle damage representing an area of uncertainty which should be addressed. On the other hand, taking into account the very low prevalence of *Salmonella* in layers in Sweden, the overall risk associated with egg washing is assumed to be low.

5 CONCLUSIONS

General

- While the shell has an array of antimicrobial properties, its structure is vulnerable and susceptible to the propagation of crack sites and so the way it is handled following oviposition requires the minimum of trauma. Egg shell quality declines with increasing bird age.

- There are basically two routes by which the egg and its contents can become infected with bacteria. These are:

    - 1) Vertical transmission, i.e., transovarian transmission of *Salmonella* spp., especially *S.* Enteritidis, which is dependent upon the presence of infected ovaries and the migration of bacteria across the vitelline membrane into the substance of the yolk during egg formation.

    - 2) Horizontal transmission, which can occur both before (internal) and after (external) shell formation. Infection of the inner egg can occur from the moment of ovulation onwards until consumption. Trans-shell movement of bacteria can occur under the appropriate conditions of temperature, humidity etc. in spite of a number of defence mechanisms to limit the effects of such an event.

- Egg-associated infections are mainly caused by *S.* Enteritidis, and in consequence, shell eggs are considered the predominant source of human salmonellosis in Europe and many other countries world-wide.

The purpose of washing eggs is to further improve the hygiene and quality of eggs by decreasing the bacterial load on the surface ("sanitizing").

TOR 1. Identify and evaluate the advantages and disadvantages of the washing of table eggs from a safety point of view

- The major advantage of using washing systems for table (Grade A) eggs is the reduction of microbial load, including foodborne zoonotic pathogens, on the surface of "clean" eggs (sanitized eggs). However, sanitizing eggs will not prevent egg related diseases caused by microorganisms, such as *S.* Enteritidis, that are internally present in eggs.
- The major disadvantage of egg washing is the potential damage to the physical barriers, such as the cuticle, that may favour trans-shell contamination with bacteria and moisture loss and thereby increase the risk to the consumer.
- Evaluation of the advantages and disadvantages of egg washing need to be related to a particular system of washing. If well done, there are clear advantages of egg washing, but poor practices increase the risk.

TOR 2. Evaluate possible options (including post washing treatments) to reduce the risks for consumers associated with this practice;

- Preventing *Salmonella* spp. infection, especially *S.* Enteritidis, in primary layer production will reduce the occurrence of *Salmonella* spp. in eggs, especially on the surface and thereby reduce the risks associated with egg washing.
- The establishment of controls whereby egg washing is part of a wider HACCP-based strategy covering all aspects of production, packing and distribution will reduce the bacterial load on the surface of table eggs and help prevent the penetration of bacteria.
- The risks associated with egg washing can be reduced by using optimal systems and the adoption of defined best practice procedures at all times.
- Promptly and thoroughly drying eggs after washing and before packing is important to avoid mould growth and bacterial trans-shell penetration.
- Oiling the cuticular surface of eggs to seal the shell pores can help to maintain internal quality during storage and can thereby reduce the risk associated with washing.
- Cooling of washed eggs and maintaining these products in this condition, can contribute to prevention of the growth of bacteria into the egg content.
- The use of UV-light in connection with washing can reduce the bacterial load further. However, the reduction depends on the dose of UV used and on the protection of micro-organism by shadow as is the case in dirty eggs.

TOR 3. Evaluate, in this context and on the basis of the elements provided by Sweden, the ability of the proposed Swedish process to provide safely washed eggs.

- Research provided by Sweden showed that washed eggs had lower microbial counts on the shell surface than unwashed eggs and no movement of microbes from the shell to the content was reported following washing.

- Specifications regarding the maximum holding time for eggs prior to washing or for the maximum iron content of the water are not given.

- No data was provided on whether the particular Swedish washing process caused any damage to the shell cuticle.

- The greatest risk in relation to egg washing is penetration of the egg by *Salmonella* spp. Therefore, in countries where the *Salmonella* prevalence in layers is very low, the risk of egg washing will also be lower. Taking into account the very low prevalence of *Salmonella* spp. in Swedish egg production, the risk associated with egg washing using the current system under strict rules is considered to be outweighed by the advantages of egg washing**.**

6 RECOMMENDATIONS

Due to a lack of scientific information on the consequences of washing Class A eggs, additional activities should be supported. This includes among others:

- To further optimise the washing process and specially the hygienic design of the equipment.
- To develop a code of practice for egg-washing systems based on critical issues described in this document and following the HACCP concept.
- To test the most appropriate post washing practices, including the effect of oiling, and especially storage conditions of washed eggs.

Developing new technologies to decontaminate the external surface of the eggshell, without damaging the shell integrity, should be encouraged.

7 REFERENCES

Bain, M.M. (1990). Eggshell strength; a mechanical/ultrastructural evaluation. PhD Thesis University of Glasgow.

Barrow, P.A. and Lovell, M.A. (1991). Experimental infection in egg-laying hens with Salmonella Enteritidis Phage Type 4. Avian Diseases, 20, 335-348.

Bartlett, F.M., Laird, J.M., Addison, C.L. and Mc Kellar, R.C. (1993). The analysis of egg wash water for the rapid assessment of microbiological quality. Poultry Science, 72, 1584-1591.

Bialka, K.L., Demirci, A., Knabel, S.J., Patterson, P.H. and Puri, V.M. (2004). Efficacy of electrolyzed oxidizing water for the microbial safety and quality of eggs. Poultry Science, 83, 2071-2078.

Board, R.G. (1966). The course of microbiological infection of the hen's egg. Journal of Applied Bacteriology, 29, 319-341.

Bolder, N.M., van Lith, L.A.J.T and Mulder, R.W.A.W. (1991). Production of *Salmonella* Enteritidis contaminated eggs after artificial inoculation of laying hens. Proceedings 10th Symposium on the Quality of Poultry meat and the 4th Symposium on the Quality of Eggs and Egg Products, Doorwerth, The Netherlands, 12-17 May; III Safety and marketing aspects: 27-34.

Bolder, N.M., Janss, L.L.G., Putirulan, F.F. and Wagenaar, J.A. (2002). Resistance of broiler outbred lines to infection with *Salmonella* enteritidis Avian Pathology (2002) 31, 581-587.

Brant, A.W. and Starr, P.B. (1962). Some physical factors related to egg spoilage. Poultry Science, 41, 1468-1473.

Brooks, J. (1951). The washing of eggs. Food Sci. Abstr., 23, 545–554.

Cranstoun, X.(1992). The influence of eggshell washing on bacterial transfer across the shell wall. M. Sc. Thesis University of Glasgow.

De Reu, K., Grijspeerdt, K., Herman, L., Heyndrickx, M., Uyttendaele, M.J., Debevere, J., Putirulan, F.F. and Bolder, N.M. (2005). The effect of UV irradiation on the bacterial load of shell eggs. Lett in Appl. Microbiol. In press.

Desmidt, M., Ducatelle, R. and Haesebrouck, F. (1997). Experimental infection with *Salmonella* Hadar in chickens: serological and bacteriological observations indicating invasive infection. Proceedings Salmonella and Salmonellosis Symposium, Ploufragan (F.), May 20-22; 251-254.

European Commission (2003). Trends and sources of zoonotic agents in animals, feedingstuffs, food and man in the European Union and Norway , pp 181-185.. (http://europa.eu.int/comm/food/food/biosafety/salmonella/zoonoses_reps_2003_en.htm)

Favier, G.L., Escudero, M.E., Mattar, M.A. and Guzmàn, A.M.S. (2000a). Survival of *Yersinia enterocolitica* and mesophilic aerobic bacteria on eggshell after washing and hypochlorite and organic acid solutions. J.Food Protection, 63, 1053-1057.

Favier, G. L., Escudero, M.E., Velàquez, L. and Guzmàn. A.M.S. (2000b). Reduction of *Yersinia enterocolitica* and mesophilic aerobic bacteria in egg-shell by washing with surfactants and their effect on the shell microstructure. Food. Microbiol., 17, 73-81.

Favier, G.L., Escudero, M.E. and Guzmàn, A.M.S. (2001). Effect of chlorine, sodium chloride, trisodium phosphate and Ultraviolet Radiation on the reduction of *Yersinia enterocolitica* and mesophylic aerobic bacteria from eggshell surface. J. Food Protection, 64, 1621-1623.

Forsythe, R.H., Ross, W.J. and Ayres, J.C. (1967). *Salmonella* recovery following Gastro-Intestinal and Ovarian Inoculation in the domestic fowl. Poultry Science, 46, 849-855.

Garibaldi, J.A. and Bayne, H.G. (1960). The effect of iron on *Pseudomonas* spoilage of experimentally infected eggs. Poultry Science, 39, 1517-1520.

Garibaldi, J.A. and Bayne, H.G. (1962). The effect of iron on the *Pseudomonas* spoilage of farm-washed eggs. Poultry Science, 41, 850-853.

Gast, R.K. and Holt, P.S. (2001). Assessing the frequency and consequences of *Salmonella* Enteritidis deposition on the egg yolk membrane. Poultry Science, 80, 997-1002.

Grijspeerdt, K., Kreft, J.-U. and Messens, W. (2004). Individual-based modelling of growth and migration of *Salmonella* Enteritidis in hens'eggs. Int. J. of Food Microbiol., 100 (1-3), 323-333.

Haines, R.B. and Moran, T. (1940). Porosity of, and bacterial invasion through the shell of the hen's egg. Journal of Hygiene, Cambridge, 40, 453-461.

Hincke, M.T., Tsang, C.P., Courtney, M., Hill, V. and Narbaitz, R. (1995). Purification and immunochemistry of a soluble matrix protein of the chicken eggshell (ovocleidin 17). Calcif. Tissue Int., 56 (6), 578-583.

Hincke, M.T., Gautron, J., Panheleux, M., Garcia-Ruiz, J., McKee, M.D., and Nys,Y. (2000). Identification and localization of lysozyme as a component of eggshell membranes and eggshell matrix. Matrix Biol., 19(5), 443-453.

Hinton, H.R. (1968). BEMB Egg Symposium Proceedings, Egg Quality - A Study of the Hen's Egg pp 251-261.

Humphrey, T. J. (1990). Growth of salmonellas in intact shell eggs : influence of storage temperature. The Veterinary Record, March 24, 292.

Humphrey, T.J. (1994). Contamination of eggs with potential human pathogens. In Microbiology of the avian egg. Board R.G and Fuller R. eds. London, Chapman and Hall, 93-116.

Hutchison, M.L., Gittins, J., Walker, A., Moore, A., Burton, C. and Sparks, N. (2003). Washing table eggs: a review of the scientific and engineering issues. World Poult. Sci. J., 59(3), 233-248.

Hutchison, M. L., Gittins, J., Walker, A., Sparks, N., Humphrey, T. J., Burton, C. and Moore, A. (2004). An assessment of the microbiological risks Involved with egg washing under commercial conditions. Journal of Food Protection, 67, 4-11.

Jones, F.T., Rives, D.V. and Carey, J.B. (1995). *Salmonella* contamination in commercial eggs and an egg production facility. Poultry Science, 74, 753-757.

Jones, D.R., Musgrove, M.T. and Northcutt, J.K. (2004b). Variations in external and internal microbial populations in shell eggs during extended storage. J. Food Protection, 67, 2657-2660.

Kim, J.W. and Slavik, J.F. (1996). Changes in eggshell surface microstructure after washing with cetylpyridiniumchloride or trisodium phosphate. J. Food Protection, 59, 859-863.

Kinner, J.A. and Moats, W.A. (1981). Effect of temperature, pH and detergent on survival of bacteria associated with shell eggs. Poultry Science, 60, 761 - 767

Knight, D.W, Bowrey, M. and Cooke, D. J. (1972). The preservation of internal egg quality using silicone fluids. Br. Poult. Sci., 13, 587-593.

Leclair, K., Heggart, H, Oggel M, Bartlett, F.M and Mc Kellar, R.C. (1994). Modelling the inactivation of *Listeria monocytogenes* and *Salmonella* Typhimurium in simulated egg wash water. Food Microbiology, 11, 345-353.

Lorenz, F.W. and Starr, P.B. (1952). Spoilage of washed eggs: 1. Effect of sprayed versus static water under different washing conditions. Poultry Science, 31, 204–213.

Lucore, L., Jones, F.T., Anderson, K.E. and Curtis P.A. (1997). Internal and external bacterial counts from shells of eggs washed in a commercial-type processor at various wash-water temperatures. J. Food Protection, 60, 1324-1328.

Messens, W., Grijspeerdt, K. and Herman, L. (2005). Egg shell penetration by *Salmonella*: a review. World's Poultry Science Journal, 61, 71-85.

Moats, W.A. (1978). Egg washing - a review. J. Food Protection, 41, 919-925.

Nascimento, V. (1992). The ease of translocation of *Salmonella* Enteritidis through the eggshell wall : an immunocytochemical and ultrastructural study. PhD Thesis. University of Glasgow.

Nield, J. M. (1992). American approach to egg washing. Cambridge Poultry Conference (UK), March 25 1992.

Padron, M.N. (1990). *Salmonella* Typhimurium penetration through the eggshell of hatching eggs. Avian diseases, 34, 463-465.

Reiber, M.A., Conner, D.E. and Bilgili, S.F. (1995). *Salmonella* colonization and shedding patterns of hens inoculated via semen. Avian Diseases, 39, 317-322.

Sabrani, M and Payne C.G. (1978). Effect of oiling on internal quality of eggs stored at 28°C and 12°C. Br. Poult. Sci., 19, 567-571.

Sauter, E.A. and Petersen, C.F. (1974). The effect of egg shell quality on penetration by various Salmonellae. Poultry Science, 53, 2159-2162.

Soljour, G., Assanta, M.A., Messier, S. and Boulianne, M. (2004). Efficacy of egg cleaning compounds on eggshells contaminated with *Salmonella enterica* Serovar Enteritidis. Journal of Food Protection, 67, 706-712.

Solomon, S.E. (1991). Egg and eggshell quality; Manson Publishing London.

SCVPH, (2003). Opinion of the Scientific Committee on Veterinary Measures relating to Public Health on Salmonellae in Foodstuffs. Adopted on 14-15 April.

Wang, H. and Slavik, M.F. (1998). Bacterial penetration into eggs washed with various chemicals and stored at different temperatures and times. J. Food Protection, 61, 276-279.

Wesley, R.L. and Beane, W.L. (1967). The effect of various wash water and internal egg temperatures on the number of thermal checks of oiled and unoiled eggs. Poultry Science, 46, 1336-1338.

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10 ANNEXES

Annex 1. Commercial Egg Washing Practices

The first mechanical egg washing systems were developed in the 1950s. Eggs on plastic trays were conveyed through washing machines fitted with high pressure nozzles which sprayed water containing detergent onto the egg shells to clean them.

As the table egg industry grew, mass candling systems were introduced as part of quality control procedures and this created a need to unload eggs from trays onto a roller or spool conveyor, so that the whole of the egg could be observed. By the 1960s, this principle was extended so that eggs could be unloaded from trays by vacuum lift and conveyed on rollers through an in-line egg washing machine. Since the egg was rolling as it passed through the washer, the cleaning process was improved because the entire surface of the shell was exposed. This basic mechanism, whereby eggs are conveyed whilst rolling through the washing machine, remains fundamentally unchanged to the present day. However, the systems, controls and safeguards have developed further.

The following sections provide a summary of the current state of egg washing technology and the methods used by major egg washing equipment manufacturers and packers around the world.

Machine Construction and Location

Large machines are generally constructed of stainless steel, although some smaller ones are made of tough polyvinyl chloride (PVC). All machines should be built to a high food industry standard and designed so that they are easy to clean, with good access to all parts of the machine (internal and external) and the facility to remove key working parts for inspection and cleaning.

Washing is normally conducted at packing centres, rather than on production farms. The location in the packing centre should be chosen so that there is good access to all sides of the machine for cleaning, inspection and maintenance. Adequate provision needs to be made for the removal of waste water and steam associated with the washing process.

Washing Mechanisms - Brushes and Water Jets

Most in-line egg washing machines use brush systems to clean eggs effectively. Brush action is combined with water to prevent the harbourage of egg and faecal matter on the brushes and to continually flush the egg whilst it is being washed. Different machines vary in terms of the volume of water used and some rely more on pressure than volume of water. Legislation normally specifies that eggs must not be submerged in water during the washing process.

Brush Action machine

Brushes are normally arranged on a series of frames and set at an angle to the eggs. Brushing may be from side to side or at right angles to the direction of movement of the eggs. In both cases, the brushes oscillate, so that they cover the entire surface and provide a balanced load on the egg so that it stays in place. This is to prevent the cleaning action causing egg rocking and shell damage.

Rotating cylindrical brushes may also be used, either instead of or in addition to brushes on frames. Some machines also include ‘end of egg’ brushing systems specifically designed to remove contamination from the poles of eggs.

The construction of the bristles and shape of the brushes is important. Bristles are normally made of nylon, but some have reinforced tips to the brush fibres comprised of fine grained sand or epoxy adhesives in an attempt to improve the washing process. In most cases, the brush sections can be raised or lowered to take account of the average size of eggs within a batch. They may also be shaped to fit the typical shape of the egg although nearly all brushes risk causing some damage to the eggs. In particular, large eggs in a batch may be damaged by excessive abrasion whilst small eggs may be inadequately washed.

To ensure efficient cleaning of the brushes and their surrounds at the end of each work period, some machines are designed so that the rows of brushes can be easily removed from the machine and cleaned separately.

Jet Action

Egg washing machines use jets of water from spray nozzles to wash eggs, either in addition to or instead of brushes. Trials have shown that water jets alone can be very effective if the nozzles are carefully designed and the jets of water are suitably angled and directed so as to produce a ‘cutting’ action on the egg.

Both brush and jet systems have the capacity to cause damage to the egg shell cuticle. Studies including those of Sparkes and Burgess (1993) have shown that very high pressure jets should be avoided since these could provide a risk of cracking, cuticle damage and of wash water being forced through the shell structure into the membranes.

Cranstoun (1992) found that both brush and jet washing processes caused some degree of cuticle damage with brush washing being the least effective in the maintenance of cuticle integrity.

Throughput and Treatment Time

In line egg washing needs to be geared to the speed of the conveyors and the egg grading operations. In practice, egg washing machines for high throughput packing centres are custom-made and the width, conveyor speed and length of the machine are adjusted according to throughput requirements. Normally, the aim is to ensure that each egg is wetted, washed and rinsed within around 60 seconds.

Water Tanks and Water Use

Most machines rely on a degree of water recirculation to reduce the costs of supply, heating and effluent disposal. Water recirculation is most effective in machines that incorporate separate water tanks for wetting, washing and rinsing. In such systems, fresh water is continually added to the rinse tank so that water is gradually displaced in turn back to the wash and then the pre-wash tank. Finally, surplus water from the pre-wash tank is disposed of. This means that as eggs proceed through the egg washing system, they are met by increasingly clean water.

It is important that all the re-circulated water is filtered frequently in order to capture any broken egg shell, feathers or other debris that may collect. As water is continuously added, care must be taken to ensure that water temperatures and chemical levels are maintained at all times (see below). It is normal commercial practice to completely empty the machine approximately every four hours so that the tanks and the filters can be cleaned and the machine be refilled with clean water.

Water Temperatures

Machines normally include a heating element in the water tank to warm up the water to the specified temperature before washing begins. However, this can lead to scale build-up in the tanks and so heat exchangers can be used as an alternative. This also means that water tanks are kept clear and are therefore easier to clean.

The target temperature for water in commercial practices is typically around 40-42°C. The final rinse water may be some 5°C higher than this.

Process Control Systems

Machine manufacturers now offer sophisticated systems for continually monitoring key aspects of the washing process, including water temperature, pH and chemical concentration, allowing problems to be identified and the process to be automatically stopped if preset parameters are not met.

However, commercial machines in countries where egg washing is permitted often lack such systems and prevailing legislation does not insist upon their use since egg washing is typically seen as comparatively ‘low risk’.

Annex 2. A Review of Commercial Egg Washing with Particular Emphasis on the Control of *Salmonella*

The following ‘blueprint’ for egg washing was drawn up in the UK as part of a study prepared for the Food Standards Agency (‘A Review of Commercial Egg Washing with Particular Emphasis on the Control of Salmonella’). It covers the following:

- The supply and pre-inspection of eggs to be washed
- Pre-washing (optional but advisable)
- The main wash
- Final rinsing
- Drying
- Storage after washing.

1 Egg supply

- There should be an effective system in place to remove all excessively dirty, cracked, broken, vulnerable (eggs with weak shells) or otherwise unsuitable eggs prior to washing.
- Washing of eggs should commence as soon after laying as possible, ideally less than 48 hours and definitely less than 7 days.
- Where eggs are stored prior to being washed, they should be kept at below 20°C under clean and dry conditions with their broad pole uppermost.

2 Equipment design - all egg washing machinery must:

- be designed to cope with the maximum expected throughput of eggs without reducing the efficacy of washing
- be constructed of suitable materials (e.g. stainless steel) so that they are easy to maintain and keep in good condition
- be straightforward to operate
- be easy to keep clean and decontaminated i.e. no corners, rims etc which are difficult to access and brushes should be easily removable
- have monitoring systems in place to ensure that all blueprint criteria such as temperatures, cleaning solution strengths and throughput times are consistently met
- have alarm systems, giving clear and immediate warnings of operational failures or deviations from pre-set wash specifications
- have automatic systems to maintain correct temperatures and solution concentrations during washing
- be designed so that the entire egg shell is cleaned
- handle the eggs and clean the shell in a way that ensures the minimum of damage occurs to either the egg shell or its cuticle
- be easily adjusted to cope with different throughputs so that eggs are kept wet for no longer than 2.5 minutes
- be adjustable so that eggs of different sizes can be effectively washed where this occurs.

3.0 Egg washing environment

- Egg washing should be undertaken in a dedicated room with good drainage.
- There should be no infestation and a recognised vermin control programme should be in place.
- All steam and vapours should be effectively removed.

4.0 Personnel

- There should be adequate personnel.

- All personnel should be trained to an adequate level in all their areas of responsibility including an understanding of food safety.
- There should be adequate management and supervision.

5.0 HACCP

- Egg washing should be incorporated into an overall documented HACCP system.

6.0 Water supply

- All water used should be of potable quality.
- Water should contain less than 2 ppm of iron.
- Only soft water should be used (between 0 and 60mg/l equivalent in calcium carbonate concentration). A suitable softener should be installed in hard water areas.

7.0 Egg washing and final rinsing procedures - general criteria

- Egg washing, rinsing and drying should be completed as rapidly as possible.
- Eggs should only be washed once, except for any pre-wash that may have been used.
- Wash solutions should be changed regularly at least every 4 hours for continuous operations. There should be evidence to support recommended frequencies.
- Eggs should not be allowed to stand or soak in water.
- Rinse solutions should not be re-circulated.

8.0 Egg washing and final rinsing procedures - operational temperatures which must be maintained

- The temperature of the wash water should be between 32°C and 45°C.
- The wash water should be least 12°C higher than the temperature of eggs to be washed.
- The temperature of the final rinse water should be higher than the temperature of the wash water by a minimum of 5°C but should not exceed 59°C.

9.0 Egg washing and final rinsing procedures - chemicals

- Chemicals for cleaning and sanitising eggs should be incorporated into the wash and final rinse solutions but only if there is good evidence that at the recommended levels and under the conditions under which they are being used they:
    - effectively remove microorganisms from the egg shell
    - do not damage the egg shell or its cuticle.

- do not affect any organoleptic (taste, texture, appearance etc) properties of the egg either before or after cooking
- are easily rinsed off, so as not to leave any potentially harmful residues
- are compatible with each other where they may come into contact
- do no harm to the equipment and do not cause scaling
- do not lead to foaming during washing and use of anti-foam agents is satisfactory
- have a neutral or alkaline pH
- are compatible with the water supply
- are safe to use and satisfy COSHH regulations.

10.0 Pre-washing

It is advisable that immediately prior to being washed, eggs are pre-wetted by spraying with water, particularly if they are quite heavily soiled. Heavily soiled eggs should not be washed.

This operation is encouraged provided:

- the temperature of the water is at least 12°C higher than that of the eggs and is a minimum of 3°C lower than that of the wash water
- the eggs can drain freely
- washing commences immediately afterwards
- the water satisfies all the criteria detailed in section 6.0.
- the pre-wash water is not re-used
- chemicals used should satisfy the criteria detailed in section 9.0.

11.0 Egg drying, storage and quality control

- Immediately after being rinsed, eggs must be completely dried ensuring no recontamination.
- Eggs should be stored at between 5°C and 15°C under clean and dry conditions with their broad pole uppermost.
- Condensation on the eggs should be avoided.
- Washed eggs should be clearly labelled in accordance with any appropriate regulatory requirements.

12.0 Commercial viability

Acceptance of egg washing by industry will also depend on its economic viability. To assess this, the economic benefits must be greater than the total costs. To complete a full assessment, information on egg washing, its benefits and costs should therefore be calculated and the latter will include.

- All capital outlay.
- Maintenance.
- Personnel.
- Operational (running).
- Waste disposal.
- Packaging and labelling.