U.S. Army scientists investigate State regulations and processes of cleaning raw feathers for use in bedding and offer a practical disinfecting procedure.

Disinfection of Raw Feathers for Bedding Material

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LARGE QUANTITIES of land and waterfowl feathers are used annually by the Armed Forces as filling materials in pillows and sleeping bags. Prior to use in these bedding items, the feather filling materials are simply "well cleaned, washed, and dried" according to military specifications (*1–4*). Although no exact procedure for cleaning, washing, and drying the feathers is outlined in these specifications, it is presumed that the feathers purchased over the past years were processed in accordance with the bedding laws of the State in which the feathers were purchased or in some instances according to the requirements set forth by the contracting officer purchasing the feathers for the Armed Forces. These procedures were apparently adequate to permit passing the feathers for cleanliness as required under these specifications. The cleanliness test consisted of determining the oxidizable matter (oxygen number) and solvent soluble matter, excluding DDT from the latter value.

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Forty-two States and the District of Columbia have enacted bedding laws which require, in addition to the cleaning, washing, and drying procedures, that all used bedding, and in many instances new bedding materials, must undergo some process to insure inactivation of all disease-bearing spores or disease-breeding germs, and removal of all filth, vermin, and extraneous organic matter. The final product is presumably clean and sanitary, but not necessarily sterile.

Various State regulations governing the sterilization of new down and feathers require the use of either dry-heat, hot water, flowing steam, steam under pressure, or fumigation. Answers to an inquiry addressed to three large eastern States indicated that very little research has actually been done on the sterilization of feathers. Similarly, little information has been published on the commercial sterilization of bedding materials by heat (*5*). The time-temperature relationships for the heat sterilization of feathers, incorporated into many State bedding laws, appear to be adaptations of the procedures used to sterilize mattresses and other bedding, with lower holding times specified in certain instances. A number of workers in the field have indicated that new feathers will be sterilized by current commercial processing. Data to support this view,

however, have not been available. Consequently, there appears to be little technical basis for the sterilization requirements of many State regulations.

Three diseases, salmonellosis, psittacosis, and histoplasmosis, transmitted to man from fowl, might be spread through the agency of feathers. *Salmonella* organisms of the types associated with salmonellosis in humans have been found in duck, hen, turkey, goose, and pigeon eggs (*6–13*). *Histoplasma capsulatum*, the causative organism of histoplasmosis, has been found in domestic fowl, soil, sawdust, and manure (*14–17*). Psittacosis has been reported in parrots, parakeets, lovebirds, canaries, chickens, turkeys, and pheasants, and the psittacosis virus has been isolated in garden soil (*18–20*).

It is most important to note that the literature does not establish any significant epidemiological or laboratory evidence that these diseases in humans are due to either exposure to or the handling of contaminated feathers.

However, since the organisms causing salmonellosis, psittacosis, and histoplasmosis in humans might be associated with feathers, the need for requiring sterilization of feathers procured for the Armed Forces has come under investigation. Although State bedding regulations use the term "sterilization," which can be interpreted as meaning disinfection, this is misleading since most feather processors do not actually sterilize feathers. Compliance would require the destruction of every form of life, be it plant or animal, visible or invisible under the microscope, harmful, or innocuous (*21*).

To avoid confusion over the use of the term "sterilization" in State bedding regulations, the position has been taken here that the sterilization requirement is not intended to insure sterile feathers in the finished article of bedding material but rather to insure the destruction of pathogenic contaminants of new feathers. If the word "sterilization" were taken literally, many feather processors would have to install new or modified equipment to meet the sterilization requirements stipulated in most State bedding regulations.

In the absence of experimental data, the purpose of this study was to determine the effectiveness of the washing, souring, and heat-drying operations in freeing feathers of potentially hazardous micro-organisms, using laboratory, pilot plant, and commercial facilities. In addition, the effectiveness of a chemical procedure for disinfecting was investigated.

Methods

Washing and disinfecting procedures for raw feathers were tested and evaluated in the laboratory and, on a larger scale, in a pilot plant and a commercial feather processing plant.

Laboratory Studies

A general washing procedure (*22*) which closely resembles the procedure used in commercial feather processing plants was first evaluated in the laboratory to determine its bactericidal and fungicidal capacity. Sterile domestic white duck feathers obtained from a commercial source and inoculated with the test organism were used in the first series of tests. The feathers were first autoclaved for 30 minutes at 18 pounds pressure and then tested for sterility by plating a sample of the feathers in nutrient agar (Difco).

Escherichia coli, ATCC No. 26, and *Aspergillus niger*, QMC No. 458, were employed as test organisms. *E. coli* was grown in nutrient broth (Difco) at 37° C. for 18 hours and *A. niger* was grown at 30° C. on Sabouraud dextrose agar (Difco) for 6 to 7 days.

Three hundred and sixty-three grams, wet weight, of the sterile feathers were placed aseptically in a laboratory tumble jar and tumbled at 27 revolutions per minute with 1 gallon of water heated to 85° F. The sterile feathers were inoculated with 150 ml. of the broth culture of *E. coli* or 100 ml. of the pooled washings of two agar slants of *A. niger*. The jar was tumbled for 1 minute to permit thorough distribution of the tracer organism throughout the feathers. A 1-ml. aliquot of the inoculated feathers was removed aseptically from the tumble jar with sterile tweezers. The sample of feathers was allowed to drain free of excess water after expelling as much of the water as possible with tweezers. The 1 gram of inoculated feathers was transferred to a Waring Blendor and blended with 99 ml. of sterile water for 1 minute. A 1-ml. aliquot of the inoculated feathers suspension was then re-

moved and plated in nutrient agar or Sabouraud dextrose agar to obtain an organism count. Triplicate samples were tested which represented the controls used in these studies.

Fourteen grams of a trisodium phosphate blood solubilizer compound were added to the tumble jar and tumbled for 15 minutes. This was the end of the first wash cycle. One gram of the washed feathers was transferred aseptically to a Waring Blendor, macerated with 99 ml. of sterile water for 1 minute and plated in the applicable agar.

In the second washing cycle, the drained feathers were washed in 1 gallon of water at 85° F. containing 0.5 ounce of liquid nonionic detergent. The feathers were tumbled for 2 minutes, allowed to soak for 13 minutes with no tumbling, and drained. Bacterial counts on the feathers were taken in the usual manner.

The third and final cycle in the washing operation consisted of adding to the tumble jar 1 gallon of water at approximately 60° F., 22.4 grams of sodium silico fluoride, and 1,865 ppm of a general purpose disinfectant (*23,24*) having the following composition: 20 percent sodium-o-phenylphenolate, 40 percent sodium 4-chloro-2-phenylphenolate, 13 percent sodium 6-chloro-2-phenylphenolate, 14–18 percent moisture, with the remainder consisting of other isomeric phenolic compounds. The final pH was between 4 and 5, and water hardness ranged between 68 and 85 ppm as calcium carbonate. The feathers were tumbled for 15 minutes and soaked for 30 minutes in this solution. One gram of feathers was transferred to a Waring Blendor with 99 ml. of water and bacterial counts determined as previously described.

It was found in this and other unpublished studies that the need for incorporating a sorbitan monoöleate-lecithin in the agar was not required because of the small carryover of disinfectant in the dilutions used, coupled with the inactivating capacity of the peptone in the nutrient agar.

Tests were also made to determine the ability of the normal washing procedure combined with the use of the general purpose disinfectant, as previously described, to reduce or destroy the natural flora found on raw feathers. The feathers used had not been autoclaved or inoculated with any organism prior to washing. Smears were made from representative survivor colonies which appeared on the agar plates using a simple alcoholic methylene blue stain.

Pilot Plant Studies

The washing and disinfecting procedure for feathers described in the laboratory studies was repeated on a larger scale in a pilot plant located in the U.S Army Textile, Clothing, and Footwear Division at the Quartermaster Research and Engineering Command (*22*).

The procedure and water sources were essentially the same as in the laboratory runs except for the amounts of materials used in the tests. Six pounds of feathers from the same lot were placed in a washer which contained 35 gallons of water at 85° F. and 3.5 ounces of a trisodium phosphate blood solubilizer compound. The feathers were agitated for 15 minutes and then drained completely. The cycle was repeated using 35 gallons of water at 85° F. and 3.5 ounces of liquid nonionic detergent.

In a third cycle, the washer was refilled with 35 gallons of tapwater at approximately 60° F. to which 3.5 ounces of sodium silico fluoride sour and 9 ounces of general purpose disinfectant (1,865 ppm) were added with a final pH reaching about 5. The feathers were held in this solution for 45 minutes, rinsed twice with warm water at 85° F., and drained. Bacteria counts were made on the feathers after each washing cycle. The results are reported in the table.

Commercial Studies

The washing and disinfecting process was also evaluated on a large scale using the equipment in a commercial feather processing plant. The washer, similar to the pilot plant washer (*22*), except for capacity and materials of construction, was made of cast iron and consisted of a large drum 8 feet long and 4½ feet in diameter with rotating paddles mounted on a central shaft. It had a capacity of 125 pounds of dry feathers.

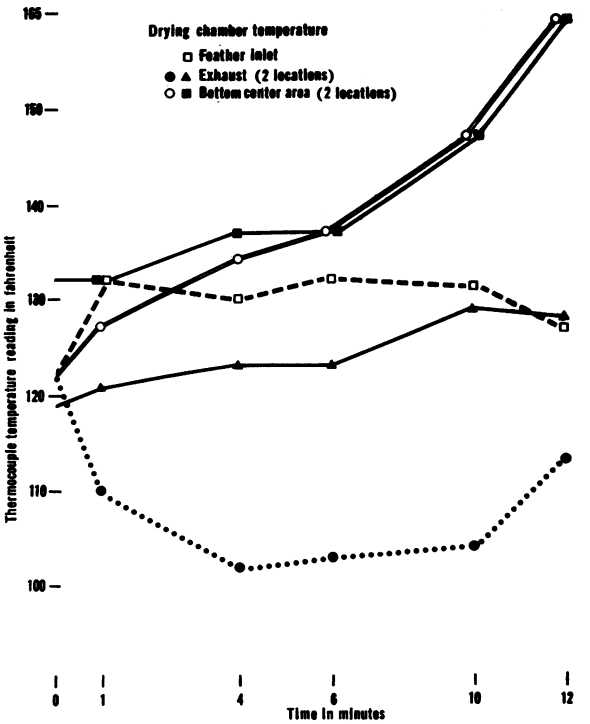
In the plant procedure, 125 pounds of raw white Long Island duckling feathers were dumped into a large washer containing approximately 500 gallons of water warmed to approximately 100° F. Sufficient liquid nonionic

detergent, or ½ bucket, about 3 pounds, plus a scoop, or about 3 pounds, of alkali, and 1 cup, or about 1 pound, of sour, were put into the washer. No attempt was made to use exact amounts of alkali, detergent, or sour, since we desired to have the feathers washed with the normal variations expected under commercial processing conditions. The feathers were washed for 10 minutes and the washer drained. The feathers were then rinsed twice with water at approximately 93° F. for 20 minutes, fed into a centrifugal extractor to remove most of the water, and placed in a steam-jacketed dryer for 10 to 15 minutes.

The dryer is essentially a steam-jacketed cylinder with a series of rotating arms mounted on a shaft running along the axis of the cylinder. As the feathers begin to dry, they become airborne due to the action of the rotating paddles. The feathers are fed into the dryer cylinder through a sliding door at one end and removed by suction through a duct at the other end. During the drying operation, air is continuously removed through an exhaust duct at the top of the dryer. It usually takes about 15 minutes to dry a 50- to 60-pound lot of feathers.

Samples were taken at the feather inlet during the drying cycle. Information on the airflow in cubic feet per minute through the dryer was not available. Temperatures were determined in the dryer by means of thermocouples placed at the feather inlet and outlet, the air exhaust, and near the bottom center of the dryer. Readings were taken at the beginning and at 1- to 4-minute intervals throughout the drying cycle. Representative temperature data are plotted on the chart. No temperature data is available from the thermocouple placed at the feather outlet since it was accidentally broken during the drying cycle. The bacteria and fungus counts on the raw feathers were also obtained before processing.

The procedure and conditions using the general purpose disinfectant were the same as previously described except that 8 pounds of the disinfectant, equal to 1,902 ppm in solution, were added to the feathers after the second rinse cycle and the feathers left in this solution for 45 minutes. Plate counts of organisms were obtained after 20- and 45-minute exposures to the disinfectant (see table).



Temperature variations in drying chamber at a commercial plant

All tests were performed within the plant where the air was dusty and filled with floating feather down. It was very difficult to prevent contamination under such conditions, especially during the sampling and plating procedures. These conditions could well account for the higher total bacteria and coliform counts obtained under commercial conditions in comparison to the laboratory tests.

Results

Results of the washing and disinfecting processes of feathers after each treatment cycle in the laboratory are reported in the table. The natural bacteria found on the feathers appear to be readily removed or destroyed by the three washing cycles, with the exception of the spore-forming bacilli. This is further substantiated by the nearly 100 percent kill obtained when sterile feathers were inoculated with *E. coli* and *A. niger*, used as tracer organisms. The nonpathogenic spore-forming surviving organism was identified as *Bacillus subtilis* by Dr. Ruth E. Gordon, Rutgers University, New Brunswick, N.J.

Four tests were conducted in the pilot plant. Organism counts were obtained only after the feathers had been washed and immersed for 45 minutes in a solution containing 1,865 ppm of the general purpose disinfectant. Although the percent kill (see table) in these tests was not as high as that obtained in the laboratory tests, all the nonsporulating organisms present on the feathers were completely killed.

A direct comparison cannot be made between the laboratory tests, and pilot plant and commercial runs, since the larger scale tests combined essentially three different wash cycles into one operation. Also, specialized media were used in an attempt to give a clearer picture of the types and numbers of organisms that survived during the washing, disinfecting, and drying procedures.

Percent kill of natural flora and inoculated organisms on feathers after washing and after disinfection with general purpose disinfectant under laboratory, pilot plant, and commercial conditions

Test runs [1]	Natural flora		*Escherichia coli* added		*Aspergillus niger* added	
	Percent kill	Counts per gram of feathers	Percent kill	Counts per gram of feathers	Percent kill	Counts per gram of feathers
Laboratory						
Control	-------	5.0×10^{4}	-------	3.49×10^{5}	-------	9.0×10^{6}
After first washing cycle	86.0	7.0×10^{3}	99.14	2.98×10^{3}	99.92	7.0×10^{3}
After second washing cycle	94.0	3.0×10^{3}	99.85	5.2×10^{2}	99.94	5.0×10^{3}
After third washing cycle and soaking in 1,865 ppm disinfectant for 45 minutes	98.8	6.0×10^{2}	99.99	1.0×10^{1}	100.0	0
Pilot plant						
Control	-------	6.4×10^{4}	-------	-------	-------	
After third washing cycle and soaking in 1,865 ppm disinfectant for 45 minutes	82.81–92.19	11.0×10^{3}—5.0×10^{3}	-------	-------	-------	

	Total flora [2]		Coliforms [3]		Molds [4]	
	Percent kill	Counts per gram of feathers	Percent kill	Counts per gram of feathers	Percent kill	Counts per gram of feathers
Commercial plant						
No disinfectant added:						
Control	-------	3.0×10^{5}	-------	4.0×10^{5}	-------	26.0×10^{4}
After washing, rinsing, and extracting	33.3	2.0×10^{5}	80.0	8.0×10^{3}	72.0	72.8×10^{3}
After drying	64.0	10.8×10^{4}	99.4	2.4×10^{3}	100.0	0
1,902 ppm disinfectant added:						
Control	-------	4×10^{5}	-------	5×10^{5}	-------	26.0×10^{4}
After washing, rinsing, and soaking for 20 minutes	99.16	3.36×10^{3}	99.2	4.0×10^{3}	100.0	0
After washing, rinsing, and soaking for 45 minutes	99.67	1.32×10^{2}	98.4	8.0×10^{3}	100.0	0
After drying	(5)	(5)	99.4	3.0×10^{3}	100.0	0

[1] Laboratory and pilot plant tests made with domestic white duck feathers; commercial plant run used Long Island duckling feathers. Surviving organisms after laboratory and pilot plant runs were spore-forming bacilli.
[2] Tryptone glucose extract agar.
[3] Eosin methylene blue agar.
[4] Cooke's rose bengal agar.
[5] Spreader on plates made it impossible to count.

Normal commercial washing and drying procedures reduced the total count of organisms by 64 percent, coliforms by 99.4 percent, and molds, 100 percent. The addition of 1,902 ppm of the general purpose disinfectant destroyed more than 99 percent of the nonsporulating bacteria and molds, with the exception of the 98.40 percent kill of coliforms after the 45-minute soaking. We believe this reduction in percent kill resulted from contamination of the plates by polluted air. As previously stated, the air was very dusty, making it difficult to maintain aseptic techniques.

Counts were not obtained of the total number of organisms after drying due to the presence of spreaders on the agar plates. Coliform and mold counts, however, were possible since the selective media used inhibited spreaders.

Data illustrated on the chart show considerable temperature variation within the chamber where the washed and disinfected feathers were dried. It should be mentioned that feathers are not static during the drying operation and that the temperature varied within the chamber between 113° F. and 165° F. at the end of the drying cycle. This means the feathers were going through a continuous heating and cooling cycle as they moved about in the dryer.

No obvious effects were found in the feathers after immersion in the general purpose disinfectant for 45 minutes and then drying. This was confirmed by the results of filling capacity and oxygen number determinations.

Discussion

The necessity for destroying the disease-producing organisms that might be found on feathers, such as *Salmonella*, *Histoplasma capsulatum*, and the psittacosis virus, can be considered a desirable public health requirement even though feathers have not been established as vectors of disease to the best of our knowledge. However, to require the destruction of nondisease producing organisms on raw feathers or to enforce sterilization prior to their use in bedding materials would appear to be costly, wasteful, and an exorbitant demand upon the commercial feather processors. Instead of enforcing sterilization, it would be much more realistic to require a pasteurization or disinfection procedure which would kill all the pathogens.

Other workers (*7*,*25*) have shown that *Salmonella* is readily destroyed at 132° F. for 20 minutes and *H. capsulatum* at 131° F. for 15 minutes. Although no data are available on heat destruction of the psittacosis virus, other pathogenic viruses are inactivated at relatively low temperatures. For example, St. Louis and Japanese B-type encephalitis viruses are inactivated at 133° F. in 30 minutes, and the Russian Far East encephalitis virus is inactivated at 140° F. in 10 minutes. Types A and B influenza virus are killed by heat at 132° F. in 20 to 30 minutes. The variola or smallpox and yellow fever viruses are inactivated in 10 minutes by moist heat above 140° F. (*25*).

From the results of this study and the information available in the literature on the effect of heat on the destruction of the pathogenic organisms suspected to be associated with feathers, a specification requiring the three-cycle washing described in the laboratory test procedure followed by exposure of the feathers to 160° F. heat for 5 minutes, should adequately safeguard the public from a possible health hazard from feathers used in bedding materials.

An alternative disinfecting procedure to the heat treatment process is to immerse the feathers in a disinfecting bath solution such as the general purpose disinfectant. Previous studies sponsored by the Quartermaster Corps (*23*, *24*) indicated that the general purpose disinfectant has a phenol coefficient of 71, which means that it is 71 times more effective in killing *Salmonella typhosa* than a 5 percent phenol solution. It is known (*25*) that 5 percent phenol will destroy *S. typhosa* in 5 minutes. The ability of the general purpose disinfectant to destroy this organism is therefore apparent. No data on the ability of the general purpose disinfectant to destroy *H. capsulatum* and the psittacosis virus is currently available. Stedman and associates (*26*) evaluated a mixture of 4-chloro-2-phenylphenolate, 6-chloro-2-phenylphenolate, and anhydrous potassium castor soap against *Trichophyton interdigitale* on inanimate surfaces and found a 99.0 percent reduction of the organism in 10 minutes. The mixture of 4-chloro-2-phenylphenolate and 6-chloro-2-phenylphenol-

ate has a reported phenol coefficient of 97 and further substantiates the fungicidal capacity of the general purpose disinfectant since it contains more than 50 percent of the sodium salts of these isomers. We have shown that a 100 percent reduction of mold spores has been obtained after 20 minutes soaking in the general purpose disinfectant.

It would appear, therefore, that the general purpose disinfectant has a powerful fungicidal capacity as well as germicidal efficiency. The only published virucidal data available on the action of phenolic disinfectants similar in composition to the general purpose disinfectant is a report on the virus of Newcastle disease, avian pneumoencephalitis (*27*). This report showed that sodium-o-phenylphenolate with a phenol coefficient of 8, at 1.0 percent concentration, destroyed the virus in 5 minutes. Since the general purpose disinfectant has a phenol coefficient of 71, it is a more potent fungicide and virucide than sodium-o-phenylphenolate but a weaker fungicide and virucide than the mixture of 4-chloro-2-phenylphenolate and 6-chloro-2-phenylphenolate. However, soaking the feathers in 2,000 ppm of the general purpose disinfectant solution for 20 minutes should allow adequate time to reduce the pathogenic organisms to a safe level. This conclusion is based on the assumption that the fungus and virus susceptibility to the disinfectant does not vary greatly from species to species within each classification.

Summary

A study of regulations in 42 States and the District of Columbia governing the sterilization of feathers revealed great variety. Little or no technical data are available to substantiate some of the sterilization requirements, especially those pertaining to the sterilization of feathers by heat. Some requirements had little or no public health significance, others contained impractical or unnecessary provisions and still others differed markedly with respect to the same item of sanitation. The present investigation was undertaken to elucidate some of the problems confronting the U.S. Army in preparing specifications to assure that feathers purchased for use in bedding materials would be acceptable by sanitation standards. A practical washing, heat-treating, and chemical disinfecting procedure for processing new feathers is described.

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