THE PEARL IN THE CHICKEN: PEARL RECIPES IN PAPYRUS HOLMIENSIS

By K. Nassau and A. E. Hanson

There are 75 recipes for the treatment of gemstones in an Egyptian papyrus copied from a work that was compiled about 200 B.C. This includes 10 recipes involving pearls, among which are two that involve feeding the pearl to a chicken. New experiments are described which confirm the validity of one such process. The other eight recipes are discussed briefly.

About 200 B.C., Bolos of Mendes, an Egyptian chemist of whom little else is known (Sarton, 1927; Partington, 1970), compiled a multivolume set of papyrus rolls under the title *Baphika* ("Dyeing"), which dealt predominantly with the techniques of coloring various substances. This work included sections on metallurgical processes, on the dyeing of wool and other objects, and on various techniques of "improving" gemstones by coloring. All copies of this work, which were presumably available in major libraries such as the one at Alexandria, have been lost, as was the fate of many works from pagan antiquity. Before this happened, however, the whole or parts of this text had been circulated in copies made by scribes.

Pliny, the Roman historian of the first century A.D., may have known this work:

> And furthermore, there are treatises by authorities, whom I at least shall not deign to mention by name, describing how by means of dyestuffs emeralds and other transparent coloured gems are made from rock-crystal, or a sardonyx from a sard, and similarly all other gemstones from one stone or another. And there is no trickery that is practised against society with greater profit. I, on the other hand, am prepared to explain the methods of detecting false gems, since it is only fitting that even luxury should be protected against deception. (Book 37, Chapters 75 and 76; from Eicholz, 1962)

Only three sources based on the work by Bolos survive. Sometime in the late third or early fourth century A.D., a scribe made copies of two lengthy excerpts in a Greek bookhand on papyrus sheets. Both were acquired in Alexandria, Egypt, by Johann d'Anastasy, a Swedish-Norwegian vice-consul in Alexandria in the 19th century. One part, consisting of 14 papyrus folia dealing with metals, gems, and cloth dyeing, is now in the Kongelige Biblioteket in Stockholm and is designated *Papyrus Holmiensis*, or *P. Holm.* (Lagercrantz, 1913; Caley, 1927; Halleux, 1981); the other, containing sections on metals, on cloth dyeing, and a short *materia medica* glossary (possibly not present in the original text), is now in the Rijksmuseum van Oudheden in Leyden (The Netherlands) and is called *P. Leyden X* (Caley, 1926; Halleux, 1981). Other copies, generally of small fragments only, some overlapping with parts of *P. Holm.* or *P. Leyden*, have been found in miscellaneous manuscripts from the 13th century and later; these were collected in the late 19th century by Berthelot (1888, 1893) in a series of volumes dealing primarily with alchemical topics.

The recipes in *P. Holm.* and *P. Leyden* deal in a very simple, factual manner with technical processes. Unlike most other alchemical or magical recipes (Taylor, 1949), a number of these recipes are quite practical and involve processes that are still in use today. Included in *P. Holm.* are 10 recipes involving pearls, among which are two that require feeding the pearls to chickens. The current paper provides a new, contemporary translation of these recipes,* describes other versions that have appeared in the literature, and then discusses the results of experiments conducted by the authors to test the validity of these ancient recipes.

THE PEARL-IN-THE-CHICKEN RECIPES IN P. HOLM.

Among the 75 gem-related recipes in *P. Holm.* are 10 that specifically deal with pearls; these are

**Translations of* P. Holm. *have appeared in German (Lagercrantz, 1913), in English (Caley, 1927), and in French (Halleux, 1981), but these were made without specific knowledge of the technology for altering color in gemstones. One of the present authors has recently investigated this area in depth (Nassau, 1984a), thus providing the impetus for a new translation and interpretation. A brief outline has appeared in the cited work (Nassau, 1984a) as well as elsewhere (Nassau, 1984b); a full translation is being prepared (Nassau and Hanson, forthcoming).*

TABLE 1. Summary of pearl treatments in *P. Holm.*

Pearl treatment	Recipe no.	Ingredients used		
		Milk	Mercury	Other substances
Cleaning	10			Honey, fig root
Cleaning	11	+		
Cleaning	12	+		Natron (sodium carbonate), earths, oil of mastic
Cleaning	13, 23	+	+	
Cleaning	25, 60			Chicken cleaning
Cleaning	61	+		Hydrated quicklime
Mordanting	13, 22, 23			Alum, vinegar
Coloring[a]	22		+	Pimpernel, houseleek, spurge
Manufacturing	18	+	+	Mica, gum tragacanth, wax, egg-white

[a]*This process may not have been intended to be used on pearls but rather on other gemstones. The word pearl appears only in the title, and an analogous recipe in Berthelot (1888, Vol. 2, p. 363, No. 47; Vol. 3, p. 348) applies to quartz.*

summarized in table 1. Eight of these involve the cleaning of dirty pearls and one describes the coloring of pearls. The last is a recipe for making an imitation pearl. Two of the cleaning recipes involve feeding the pearl to a chicken:

No. 25. Whitening for a Pearl

A pearl which has become encrusted is made white in this way: give it to a chicken to swallow, thereupon cut it [the chicken] open and you will find it has become white.

A similarly worded recipe specifying sunset to sunrise and a thirsty chicken appears in Berthelot, 1888 (vol. 2, p. 369, no. 8; vol. 3, p. 354). Berthelot, 1893 (vol. 2, p. 175, no. 104) mentions one that includes among other ingredients lemon juice and uses a pigeon slaughtered after two hours; Berthelot, 1888 (vol. 2, p. 330, no. 38; vol. 3, p. 316) provides one that uses a chicken or a pigeon with no time interval specified.

Halleux (1981, p. 189, Note 3) tried to test this process using a "fake gemstone" and a duck! This was not a valid check, since a "fake gemstone" would not react with gastric juices the way a pearl would.

No. 60. Cleaning a Pearl

Whenever a real pearl becomes dirty and has lost its lustre, the Indians clean it in this way: they cast the gem as food to a rooster in the evening. In the morning they search the droppings and discover it has been cleaned inside the bird and that it possesses in addition a whiteness not inferior to the original.

An additional version of the cleaning-in-a-chicken process is noted by Kluge (1860):

The 'Asiatic Journal' reports (January 1825) that in Ceylon those pearls that have lost their sheen with the passage of time are given to chickens to swallow and then they are killed after one minute. The pearls are then found in the stomach and are as beautiful as at that moment when they were removed from the mollusk. Such a polishing can be imagined to derive from the worm-like motions in the muscular stomach of the birds. (Translated from the German)

The process described in recipes 25 and 60—and the parallel recipes in Berthelot (1888, 1893) and in Kluge's report—seem reasonable when one recalls that pearls are composed of layers of tiny crystals of the aragonite (and possibly the calcite) form of calcium carbonate, held together by about 10% of conchiolin, an organic substance (Webster and Anderson, 1983). Accordingly, the acid gastric juices of the stomach and the grinding action of the gizzard might be expected to dissolve the stained surface layer of aragonite and so improve the appearance of a dirty-looking pearl.

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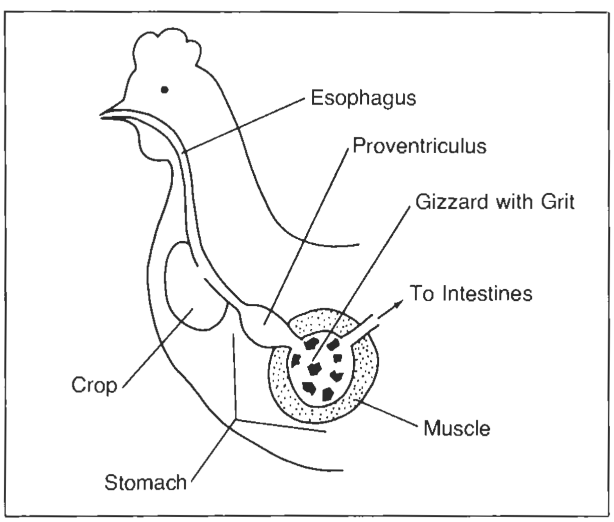
All photos are by K. Nassau.

The Halleux (1981) experiment with a "fake gemstone" could not have confirmed this pearl-cleaning process and, since no other modern attempts to test the validity of this process appear to have been published, new experiments were clearly desirable.

To understand the significance of such a process, a brief description of a chicken's digestive processes is required (Sturkie, 1976). As shown in figure 1, the food eaten by the chicken first passes through the esophagus into the crop. Here food is held under moist and mildy acidic conditions (pH about 4.5) until there is room for it in the stomach; if the chicken has not eaten for some hours, then the residence time in the crop is very brief and food moves rapidly into the stomach.

The stomach consists of two parts: (1) the proventriculus, where gastric juice (containing hydrochloric acid and the protein-digesting enzyme pepsin) is added and where the residence time is very short; and (2) the gizzard, where there is a longer holding stage under strongly acidic conditions at a pH as low as 1.4 (Sturkie, 1976). Since the chicken has no teeth to grind up its food particles for maximum exposure to the digestive juices, this process is performed by strong contractions of the muscular walls of the gizzard acting on pebbles that the chicken has pecked up along with its food. The digested food next moves into the intestines for absorption; the addition of pancreatic juice now neutralizes the acid and produces conditions that would not be expected to affect a pearl. The total digestive process normally takes about three hours. The pebbles remain in the gizzard for a week or even longer.

Figure 1. The digestive system of the chicken.



THE NEW PEARL-IN-THE-CHICKEN CLEANING EXPERIMENTS

The First Three Experiments. The first part of this study used eight soiled typical round Japanese cultured *Pinctada martensi* pearls. The pearls were color matched into two sets (nos. 1A and 1B to 4 and nos. 5 to 7; nos. 4 and 7 were not treated so that they could serve as the color standard for their respective groups) and then washed, carefully weighed, and measured before use. All drilled pearls were drilled through so that the hole could be cleaned out before weighing. These pearls ranged from 6.8 to 7.8 mm in diameter and had a cultured layer about 0.35 mm thick grown over mother-of-pearl beads; details of the growth and characteristics of such pearls may be found in Webster and Anderson (1983).

The chickens used were adult (about one year old) male White Leghorns at the Poultry and Small Animal Research Facility, Cook College, Rutgers University; the experiments were conducted shortly before the birds were to be dispatched for other purposes. The feeding and recovery were supervised by Mr. M. J. Sennell of that facility. A total of four experiments were conducted.

The first experiment was an attempt to duplicate the process described in recipe 60 using two pearls, nos. 1A and 1B. Neither had appeared in the droppings the next morning or even after 46 hours, at which time the chicken was dispatched. Only two small fragments were found in the gizzard; they are shown in figure 2 and measurements are given in table 2. Both of these pearls had been split by the grinding action and at least 0.8 mm had been dissolved or ground from the surface of the largest remaining piece; all of the cultured nacre had been removed. The grinding and acidic conditions in the gizzard are obviously strong enough to destroy a pearl completely. Also, it is clear that the pearls were being treated like gravel and would not have passed out of the gizzard overnight; this aspect of recipe 60 is clearly wrong.

In the second experiment, the milder conditions in the crop were examined by exposing pearl no. 2 for only one hour in a well-fed chicken so as to maximize the holding time in the crop. The pearl was indeed found in the crop; it had lost no weight (the slight increase recorded probably corresponds to absorption of a little moisture) and its

Figure 2. Pearls no. 1, 2, and 3 from the first three pearl-in-the-chicken experiments; no. 4 is the untreated color match.

appearance was unchanged, as shown in table 2 and figure 2. The one-minute treatment time given by Kluge (1860) is therefore clearly incorrect.

In the third experiment, pearl no. 3 was fed to a chicken that had not eaten overnight, so that the pearl should move rapidly through the crop. This pearl was recovered from the gizzard after two hours and was found to have lost 0.0160 g, which corresponds to a thickness of 0.034 mm, using a specific gravity of 2.7 in the calculation; see figure 2 and table 2. This pearl has lost about one-tenth of its cultured layer. It is interesting that the rate of loss of 0.017 mm per hour in this experiment was essentially the same as the 0.018 mm per hour loss recorded in the first experiment.

The pearl used in this third experiment is now much lighter in color than it was before the experiment and it still possesses an excellent luster—the brilliant reflection of light at the surface—and an excellent orient—the rainbow-like sheen produced by the diffraction of light at the surface (Webster and Anderson, 1983; Nassau, 1983). Accordingly, one can conclude that recipe 25 represents a valid way of cleaning a pearl by removing a thin layer from the surface while maintaining an excellent surface quality.

TABLE 2. The first three pearl-in-the-chicken cleaning experiments.

	Pearl no.		
Variables	1A/1B[a]	2	3[b]
Time in chicken (hours)	46	1	2
Location of pearl	Gizzard	Crop	Gizzard
Initial diameter[c] (mm)	7.5/7.8	6.8	7.4
Initial weight (g)	1.2135	0.4353	0.5695
Final weight (g)	0.2530	0.4357	0.5535
Weight loss (%)	79.2	0.0	2.81
Thickness lost (mm)	0.8	0.0	0.034[d]

[a]*Two pearls used; weights and weight loss are total, thickness lost is for one pearl only.*
[b]*This was performed after the chicken had fasted overnight.*
[c]*Color reference pearl no. 4 shown in figure 2 is 7.7 mm in diameter.*
[d]*Calculated from weight loss; equals half of diameter loss. Direct measurement was not possible because the pearl was not perfectly round.*

The Pearl-in-Acid Experiment. An obvious question that arose at this point was: Can one use a dilute acid to achieve this same end? Either in vivo in the chicken or in vitro in the test tube, the dissolving action, using hydrochloric acid as the typical gastric (Sturkie, 1976) or experimental acid, is:

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

The amount of dissolution found with the third experiment corresponds to the evolution of 2.4 cc of carbon dioxide gas, assuming the presence of 10% conchiolin. Accordingly, pearls no. 5 and 6 (see table 3) were exposed to different concentrations of dilute hydrochloric acid (1:100 and 1:400, respectively) with occasional stirring at room temperature. The loss of weight approximately equal to that of the third experiment required 20 minutes and three hours, respectively, for the two pearls, so that these concentrations bracket the rate of loss that produces the desired results in a chicken.

Both of these pearls did lighten considerably, but they lost much of their luster as well as most of their orient (figure 3). Examination under the microscope showed considerable surface pitting, in contrast to the smooth surface retained by

TABLE 3. The pearl-in-acid cleaning experiment.

Variables	Pearl no. 5	Pearl no. 6
Conc. HCl in water (vol.)	1 in 100	1 in 400
pH	0.9	1.5
Time (hours)	0.3	3
Initial diameter[a] (mm)	6.9	7.0
Initial weight (g)	0.4733	0.4852
Final weight (g)	0.4612	0.4696
Weight loss (%)	2.56	3.22
Thickness lost[b] (mm)	0.032	0.038

[a]Color-reference pearl no. 7 shown in figure 4 is 7.0 mm in diameter.
[b]Calculated from weight loss.

Figure 3. Pearls no. 5 and 6 from the acid cleaning experiments; an abrasive has also been used on no. 6; no. 7 is the untreated color match.

chicken-cleaned pearl no. 3 (which was still slightly rough to the tooth, however). In addition, loose shreds of conchiolin were seen on the surface of pearls no. 5 and 6. When this was removed by rubbing pearl no. 6 between the fingers with a very mild abrasive (White Rose All Purpose Liquid Cleanser with Mild Abrasive—containing calcium carbonate), the surface remained pitted; the luster improved slightly but the orient did not improve significantly. For details, see table 3 and figure 3.

The reason for this difference in behavior clearly derives from the specific conditions in the chicken's gizzard. It is well known that during metallurgical etching and electrolytic deposition or polishing (Lowenheim, 1953) the presence of additives can modify a rough surface into a smooth one; the various enzymes, food particles, and organic substances present in the gizzard may provide this same function in the chicken; the grinding action of the gizzard may also help in keeping the surface smooth. An additional factor involves the conchiolin exposed when the acid dissolves the aragonite crystals from the surface of the pearl; this can be removed in the chicken both by the grinding action and by the attack of the protein-digesting enzyme pepsin present in the gizzard, thus maintaining a smooth surface.

It may well be that some type of mild tumbling used in conjunction with a suitably modified acid solution, possibly combined with pepsin, could produce results as good as those in a chicken, but no further experiments were performed on this point.

The Fourth Experiment. The fourth and final chicken experiment explored several additional questions: Can larger pearls be treated? Can several pearls be treated at one time? What is the reaction of freshwater pearls? What is the effect on an abraded pearl? The results are summarized in table 4 and figures 4 to 6. In this experiment, additional *Pinctada martensi* saltwater pearls as well as baroque cultured freshwater *Unio* pearls (Sweaney and Latendresse, 1984) were used.

Eight pearls were fed at one time to a chicken, but one was spit up (unnoticed at the time) and is therefore omitted from the data. The average weight loss of 4.05% after three hours corresponds to a loss rate of 1.35% per hour, which is close to the 1.72% per hour loss for pearls no. 1A and 1B and the 1.40% per hour loss of pearl no. 3. Some variability in weight loss can be seen in table 4, which suggests that the pearls did not all move from the crop into the stomach at the same time. The treatment of several pearls at one time is thus clearly feasible, but only with some loss of control.

Well-matched color reference pearls were not available for this experiment, but a definite lightening of the color was observed in the saltwater pearls, as expected. Of the freshwater pearls, one (no. 11) lightened in color but two others (nos. 12 and 13) turned slightly yellowish. The luster and orient of these seven pearls were generally unchanged except for the black pearl, no. 14, which lost most of its strong rosé and green overtones; it was, however, of extremely poor surface quality to begin with.

To test the effect of this procedure on abraded pearls, pearls no. 10 and 15—which were similar in size, luster, and orient (but not in color)—were abraded with a fine file so that a flat spot was created on each, extending well into the mother-

TABLE 4. The fourth pearl-in-the-chicken cleaning experiment.

Pearl no.	Type[a] and description	Min and max. dimensions (mm)	Initial weight (g)	Weight loss[b] (%)	Change in appearance[c]
8	S, green-yellow	7.3	0.4645	4.89	Somewhat lighter
9	S, silver-gray	7.4	0.5248	2.78	Somewhat lighter
10	S, yellow-white[d]	6.8	0.4564	4.55	See text and figures 5 and 6
11	F, blue-gray	14.5 × 5.8	0.7500	5.17	Somewhat lighter
12	F, gray-white	7.6 × 6.9	0.5255	3.52	V. slightly yellower
13	F, gray-white	9.4 × 8.8	1.1251	3.72	V. slightly yellower
14	F, black	10.5 × 7.3	0.7261	3.75	Less orient, less surface color
				Average: 4.05	

[a]*S = near-round cultured saltwater* Pinctada martensi *pearl; F = baroque cultured freshwater* Unio *pearl.*
[b]*All of the pearls were exposed for three hours after the chicken had fasted overnight; all were found in the gizzard.*
[c]*Characteristics not listed did not appear to change significantly.*
[d]*The abrasion-matched (but not color-matched) pearl no. 15 shown in figure 5 is 7.0 mm in diameter.*

of-pearl seed. Pearl no. 10 was then fed to the chicken as part of the fourth experiment, while pearl no. 15 was held back as the control. As can be seen at least partially in figure 5, the rough nacre surface of pearl no. 10 was polished in the gizzard to produce a quite acceptable luster and an excellent orient. Microscopic inspection shows the presence of slight circular ridges on this part of the pearl, corresponding to the concentric layers of nacre.

Figure 4. Pearls no. 8 to 14 from the fourth pearl-in-the-chicken experiment; the bottom row shows three of the pebbles also recovered from the gizzard.

Figure 5. Pearls no. 15 (left) and no. 10 (right). Both were abraded, but only no. 10 was then "polished" in a chicken.

Another region of pearl no. 10, which showed prominent surface ridges, had been filed down to flatten the surface. Here, too, the file marks disappeared during the treatment and an excellent luster and orient resulted, as shown in figure 6. It should be pointed out that such ridges and other irregularities appearing over a spherical seed are produced by irregular deposits of conchiolin (and possibly aragonite) in non-nacreous form, as can be seen in the cross-section of such a baroque saltwa-

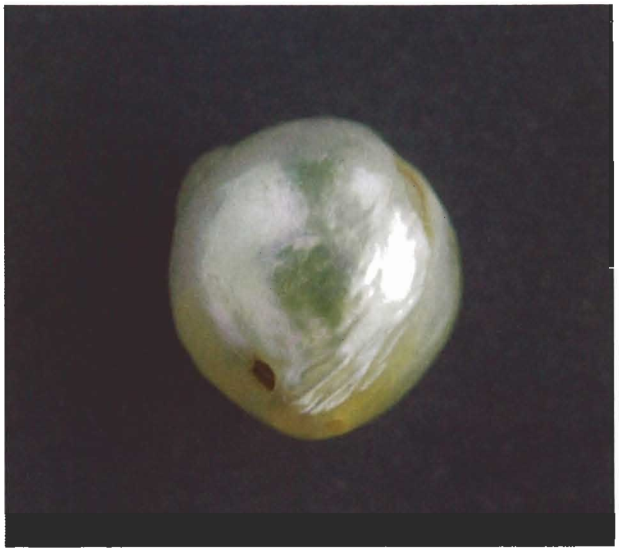


Figure 6. Ridged area of pearl no. 10 which was first abraded and then polished in a chicken.

ter pearl shown in figure 7. Abrasion to improve the surface of a pearl can obviously be performed only by remaining within the nacreous layer, but the rough filed surface can then be polished in a chicken by following the described procedure. It should, however, be noted that a ridged appearance originating from the deeper nacre layers may still be visible through the translucent upper layers even though the surface is now smooth; this is the case for part of pearl no. 10, as seen in figure 6.

These experiments demonstrate that the appearance of some pearls may indeed be improved by the pearl-in-the-chicken process described in *P. Holm.* recipe 25. Since nacre is removed, it is obvious that surface stains would be removed along with the nacre.

THE OTHER PEARL RECIPES

A summary of the other eight pearl recipes in *P. Holm.* is given in table 1; new translations have been prepared (Nassau and Hanson, forthcoming).

The "law of similarity" (Frazer, 1947)—or "principle of analogy" (Lloyd, 1966)—influenced the thinking in many early societies and can be recognized in some of these recipes. According to this habit of thought, like affects like: If you wish something to be white, then place it in contact with a white substance and it will acquire the quality of whiteness. This might explain the use of milk in five of these recipes, particularly milk from a *white* dog (specified in recipes nos. 11 and 61). Milk is only very slightly acidic and a specific chemical interaction with a pearl would not be expected. Again, mercury, with its metallic sheen, might have been expected to intensify a pearl's orient by similarity and analogy.

Of the six pearl-cleaning recipes of this group, one (no. 11) uses cold milk only and two (nos. 13 and 23) heat milk with mercury, although it is not actually specified if the pearl is immersed while the mixture is still hot. Three recipes (nos. 10, 12, and 61) use poultices, sticky or congealing substances, which are applied to the pearl and then

Figure 7. A baroque Pinctada martensi *pearl cut in half to show non-nacreous regions between the spherical seed and the irregular surface.*

rubbed (nos. 10 and 61) or peeled (no. 12) off. Two of these (nos. 12 and 61) are applied cold, but the third is applied hot; heat can damage a pearl. In all of these recipes, no more than a mere physical removing of surface dirt appears to be involved; one suspects that soap would do as good a job.

Mordanting is involved in two of the cleaning recipes (nos. 13 and 23) and in the coloring recipe (no. 22). A mordanting step, most frequently employing alum and vinegar, was used in Greco-Roman times in the major process for dyeing wool and has continued to be so used until quite recently (Taylor and Singer, 1956). It involves the precipitation of finely divided aluminum hydroxide onto the fabric and the subsequent attachment of a dye to this powder. As a result, the dye becomes more intense in color and does not fade as rapidly in sunlight. Although it would almost certainly not have served any useful function for cleaning a pearl, mordanting must have seemed a step that might be useful—a slight etching produced by the vinegar, perhaps—and probably did no harm. A mordanting step could be more meaningful to a coloring (dyeing) process such as that described in recipe no. 22, although it may be that this recipe was never intended to be used on a pearl. Merely from the list of ingredients it is not possible to guess what color would be produced by this mixture.

Finally, there is recipe no. 18, which instructs how to make an imitation pearl from a paste. The use of ground-up mica seems appropriate here since this would tend to give a surface shimmer to the imitation, much as does the "fish-scale essence" that has been used to make imitation pearls since 1656 (Webster and Anderson, 1983). No less than three of the ingredients, used in equal amounts, could be expected to contribute to the hardening of the kneaded mass: gum tragacanth, wax, and egg-white. One suspects that the product would not have been a very convincing pearl imitation except to the quite inexperienced.

CONCLUSION

The chicken-cleaning experiments here reported, as well as other duplication experiments currently under way, indicate that many of the 2,000-year-old recipes given in *P. Holm.* represent valid gemstone-treatment processes. Pliny, writing in the first century A.D., described the sugar-acid agate-dyeing process, the use of foils, dyeing, the oiling of emerald, the making of triplets, and even the clarification of amber (Nassau, 1984a and b). *P. Holm.*, based on the even earlier writings of Bolos, provides us with details of some of Pliny's more obscure passages (it explains, for example, the "softening" of "diamond" with warm goat's blood) and adds such treatment processes as the cracking and dyeing of quartz and the oiling of emerald with Canada balsam. This unique manuscript represents an early comprehensive technical text and attests to the antiquity of gemstone-treatment processes.

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