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Ordnance Gelatin for Ballistic Studies

Detrimental Effect of Excess Heat Used in Gelatin Preparation

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Most users of ordnance gelatin for ballistics studies are apparently unaware of the detrimental effects on this tissue simulant's properties caused by excess heating in reconstitution of the gelatin powder. Material published by the Gelatin Manufacturers Institute of America states that heating gelatin above 40°C can be detrimental to its properties. The manufacturer of type 250 A Ordnance Gelatin does not include directions for preparation with the gelatin powder. Directions that can be obtained by contacting the manufacturer fail to give any recommendations on the amount of heat applied during gelatin preparation and do not mention the detrimental effects of excess heat. These oversights are corrected in the revised set of directions included in this article.

Key Words: Tissue simulants—Ballistic injury—Gelatin.

The Gelatin Manufacturers Institute of America cautions that "Gelatin's most useful properties, gel strength and viscosity, are gradually weakened on prolonged heating in solution above about 40°C" (1). We became aware of excess heat's deleterious effect when we inadvertently heated a batch of type 250 A Ordnance Gelatin to 70–80°C during preparation. After this gelatin was removed from the molds, it was found to be much softer than previous batches. We contacted Kind and Knox Division of Knox Gelatine (Sioux City, Iowa, U.S.A.), manufacturer of the 250 A Ordnance Gelatin, who told us that heating gelatin to over 40°C during its preparation is likely to ruin the very properties that make it so useful as a tissue simulant. They sent us their directions for reconstituting the Ordnance Gelatin powder, which do recommend "always start with cold water."

The overwhelming majority of users to whom we have posed the question tell us they start with boiling water in reconstituting their gelatin powder. We suspect that, because the manufacturer did not provide directions with the gelatin powder, the users assumed that they should prepare the ordnance gelatin as they prepare Jell-O, that is, with boiling water.

Listed below are the directions furnished (on request) by the Kind and Knox Division of Knox Gelatine. We have added, in italics, cautions that we feel need to be observed to assure uniformity of gelatin blocks and the quantities of gelatin and water used to make a 10% gelatin solution (2). In direction 5, in which the application of heat is mentioned, no limitation was included. Obviously one is needed and we have added it.

GENERAL PROCEDURES FOR RECONSTITUTING GELATIN

1. Always start with *cold*—45–50°F (7–10°C)—water.
2. Always add the powdered gelatin to the water. Never

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pour water into gelatin. Use *1,000 g gelatin with 9,000 ml water. (This gives 10% solution.)*
3. Agitate (by stirring) a bare minimum just to wet all particles (avoid violent agitation to prevent entrainment of large quantities of air).
4. Let stand in refrigerator for 2 h to hydrate all gelatin particles.
5. Heat the container in a hot water bath or double cooker, and again stir gently until all gelatin is in solution and evenly dispersed throughout the container. *Do not heat over 104°F (40°C)!* Do not stir rapidly, to prevent entrainment of air.
6. Pour into molds, set in refrigerator or cold—45–50°F (7–10°C)—water bath until firmly set. (Leave overnight for best results.)
7. *After removal from molds, store in refrigerator at 39°F (4°C) in airtight plastic bags. Do not use blocks until at least 36 h have elapsed from the time gelatin was poured into molds.*

GENERAL NOTES

1. Gelatin is insoluble in cold water.
2. Final concentration will depend on desired firmness of block.
3. Firmness of block will increase with time in cold water bath, up to 24–30 h.
4. Blocks may be reused simply by heating to melting temperature then rechilling as in original procedure.
5. *Add 5 ml propionic acid (pure stock solution obtained from Fisher Scientific, Fair Lawn, NJ, U.S.A.) per liter to inhibit mold (optional).*
6. *Gelatin firmness varies greatly (inversely) with temperature of the block. Gelatin temperature must be constant throughout each block and there must be no temperature variation between blocks. We shoot our gelatin blocks within thirty minutes of removal from the refrigerator. We measured the temperature 2 cm from the block surface; it takes 90 min to rise 1°C in our shooting range which is kept at about 68°F (20°C).*

DISCUSSION

Fortunately, we ruined the aforementioned batch of gelatin in the very beginning of our studies [during the process of calibrating this tissue simulant against living swine muscle (2)], before it could affect any experimental results. However, in comparing results with two other investigators, we found that abnormally large temporary cavities were produced in their gelatin (as seen on high-speed cine films), and yet the cracks left in the gelatin were very small. In each case, the erratic results were traced to a gelatin prepared with boiling water rather than with cold water as recommended by Kind and Knox (direction 1, above). The excess heat had weakened the gelatin's strength and it provided less resistance to being displaced by the temporary cavity.

Berlin et al. (3) reported erratic experimental results with gelatin dissolved in water at 85–90°C. They reached the erroneous conclusion that gelatin is not a suitable tissue simulant, obviously unaware that they had degraded their gelatin by the use of excess heat in its preparation. Others report heating their ordnance gelatin to ". . . at least 65°C . . ." (4), ". . . 90–95°C . . ." (5), ". . . 75°C . . ." (6) in its preparation.

Some investigators, with whom we regularly compare results, produce apparently reliable gelatin despite beginning with water hotter than recommended. The disruption of the gelatin molecules by heat appears to be similar to that seen in cooking food, and is certainly a function of the degree of heat *and* the length of time the heat is applied. We are not saying that exceeding 40°C, especially if for a short period, disrupts enough gelatin molecules to make a noticeable difference, but we suggest that following the above directions should add some measure of security and margin for error.

It is unfortunate that many experiments have been flawed because the investigator was unaware of excess heat's disruptive effects on gelatin. This article should provide information to insure uniform gelatin that will yield reliable results in future ballistics experiments.* □

REFERENCES

1. Gelatin Manufacturers Institute of America, Inc. *Gelatin.* New York: Gelatin Manufacturers Institute of America, 1982.
2. Fackler ML, Malinowski JA. The wound profile: a visual method for quantifying gunshot wound components. *J Trauma* 1985;25: 522–9.
3. Berlin R, Janzon B, Rybeck B, Sandegard J, Seeman T. Local effects of assault rifle bullets in live tissue. Part II. *Acta Chir Scand* 1977;(suppl)477:7.
4. Bruchey WJ Jr, Frank DE: *Police handgun ammunition incapacitation effects. II. Experimental data.* National Institute of Justice Rep 101–83. Washington DC: US Government Printing Office, 1984:5.
5. Lewis RH, Clark MA, O'Connell KJ. Preparation of gelatin blocks containing tissue samples for use in ballistics research. *Am J Forensic Med Pathol* 1982;3:181–4.
6. Charters AC III, Charters AC. Wounding mechanisms of very high velocity projectiles. *J Trauma* 1976;16:467–70.

* On their request, we sent Kind & Knox Division of Knox Gelatine Inc. (Sioux City, Iowa) a letter (on 29 June 1987) calling to their attention the problems outlined in this article. We strongly recommended that they add to their directions the caution on applying excess heat and that they enclose the modified directions in each cannister of type 250 A Ordnance Gelatin powder.