Properties of Acrosomal Hyaluronidase from Bull Spermatozoa

EVIDENCE FOR ITS SIMILARITY TO TESTICULAR HYALURONIDASE*

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SUMMARY

Sperm acrosomes contain hyaluronidase, the amount varying, respectively, from ram, rabbit, bull, human, boar, rat, and stallion sperm to rooster sperm that do not possess this enzyme.

Hyaluronidase was partially purified from bull sperm acrosomal extracts by DEAE-cellulose chromatography. Bull sperm acrosomal hyaluronidase has an optimum pH of 3.75 and is not effected by freezing and thawing or refrigeration, but it is unstable at a pH below 3.0 or temperatures above 50°C. The enzyme requires salt for stability and activity and is inhibited by Fe++ and Fe+++ ions or heparin but not by Mn++, Mg++, and Ca++ ions or EDTA. Partially purified acrosomal hyaluronidase from rabbit spermatozoa possesses the same properties. The molecular weight of the hyaluronidase of bull sperm acrosomal extracts was estimated to be 110,000 by gel filtration using a Sephadex G-100 column. The acrosomal proteinase-proteinase inhibitor complex appeared as a separate fraction with a molecular weight of 68,000.

The activity of bull testicular hyaluronidase as well as bull sperm acrosomal hyaluronidase is inhibited by rabbit immunosera prepared against bull testicular hyaluronidase preparations or bull sperm acrosomal extracts. Immuno-diffusion experiments showed that bull testicular hyaluronidase and bull sperm acrosomal hyaluronidase preparations have only one component in common. This component was demonstrated to be the hyaluronidase. The results suggest that sperm acrosomal hyaluronidase is identical with testicular hyaluronidase but is apparently different from lysosomal hyaluronidase, present in organs other than the testis.

A large variety of organs and tissues possess hyaluronidase. In all of these, except the testis, hyaluronidase was shown to be of lysosomal origin (1–7). Lysosomal and testicular hyaluronidase differ significantly (7). The biochemical properties of lysosomal and testicular hyaluronidase have been studied extensively (5–8), although a highly purified preparation of testicular hyaluronidase has just recently been obtained (9).

McClean (10) and Hoffmann and Duran-Reynals (11) first indicated the presence of hyaluronidase in spermatozoa. Later, the enzyme was shown to be associated with the sperm head and in particular the acrosome or head cap (12–14). The hyaluronidase activity of a semen sample correlates with the number of sperm (15), and the hyaluronidase of seminal plasma was shown to originate from sperm and not from the accessory glands (16).

Hyaluronidase disperses the cumulus oophorus on addition to ova (17, 18), a process that can be inhibited using hyaluronidase inhibitors (14, 19, 20) or antisera (21, 22). It is generally assumed that sperm use this enzyme to lyse a path through the cumulus (23). Various authors reported an increase in the fertilizing capacity of sperm on addition of hyaluronidase (24, 25). Treating sperm with hyaluronidase inhibitors resulted in a decrease in fertility (20, 26). These data indicate that the inactivation of acrosomal hyaluronidase may be a feasible approach in the development of new contraceptive agents.

Except for a brief statement about the pH optimum of the hyaluronidase of human spermatozoa (4), no data are available concerning the characteristics of sperm acrosomal hyaluronidase. This article describes the partial purification and some of the properties of bull sperm acrosomal hyaluronidase. Identity with testicular hyaluronidase was evaluated both biochemically and immunochemically. The hyaluronidase activities of sperm acrosomal extracts from various species and some of the properties of partially purified rabbit sperm acrosomal hyaluronidase were also determined. A preliminary report was presented previously (27).

EXPERIMENTAL PROCEDURE

Enzyme Assays—Hyaluronidase assays were performed by a modification of the methods of Bollet et al. (1) and Aronson and Davidson (6). In a tube, 0.3 ml of hyaluronic acid (Worthington) at a concentration of 0.8 mg per ml in 0.1 M acetate buffer, pH 3.8, containing 0.15 M NaCl was mixed with 0.2 ml of the enzyme solution and incubated at 37°C for 1 hour. The mixture...
was adjusted to pH 8.9 by addition of 0.1 ml of 0.8 M potassium tetraborate buffer, pH 9.1, and 0.25 ml of 1 M NaOH and tested for N-acetylhexosamine released according to the method of Roiioig et al. (28). Controls were made by either omitting the enzyme or the substrate. N-Acetylglucosamine (Sigma) was used as standard. One unit of hyaluronidase activity was defined as that amount of enzyme that causes the release of 1 μmole of N-acetylglucosamine in 1 hour at 37°. Specific activity was recorded as the number of units per mg of protein assuming that 1 mg of protein per ml has an optical density of 1.0 at 280 nm using a 1-cm light path. Bovine testicular hyaluronidase was obtained from Worthington and β-glucuronidase from Warner Chilcott Laboratory (General Diagnostics Division). Acrosomal proteinase determinations were made using benzoylarginine ethyl ester (BAEE, Sigma, 10 mg per 50 ml) (29) in 0.1 M borate buffer, pH 8.0, containing 0.05 M CaCl2 as substrate (30). The presence of a proteinase-proteinase inhibitor complex was indicated by an increase in activity after incubation of the solutions at pH 3.0 (31).

Preparation of Acrosomal Extracts—Rams, rabbits, boars, stallions, roosters, and human ejaculated sperm were collected and treated immediately, whereas the bull sperm was obtained frozen in pools of 100 ejaculates from Eastern Artificial Insemination Company, Ithaca, New York and Curtiss Breeding Service, Cary, Illinois. Rabbit and rooster sperm were treated in pools of 40 ejaculates and human sperm in pools of 15 ejaculates. The ejaculates of the other species were treated individually. Epididymides were either obtained fresh from the School of Veterinary Medicine, University of Georgia, or were purchased from Pel-Freez Biologicals and shipped on ice. The epididymides were flushed according to Polakoski et al. (32), and the sperm solutions were treated individually except in the case of the rabbit where the sperm of 40 epididymides were pooled before treatment. To remove the seminal or epididymal plasma, the sperm were repeatedly washed using Krebs-Ringer phosphate buffer, pH 7.0, and centrifugation at 700 x g for 15 min. Extracts were prepared by incubation of the sperm with 0.075% Hyamine 2389 (Rohm and Haas Co.) and 0.075% Triton X-100 (Rohm and Haas Co.) for 30 min at 37° according to the method of Hartree and Srivastava (33). This results in the removal and partial solubilization of the acrosome but leaves the other structures of the spermatozoon intact. The acrosomeless sperm were removed by centrifugation at 700 x g for 15 min. The acrosomal enzymes were precipitated from the supernatant solution by addition of ethanol (80%), and the precipitate was dialyzed against distilled water and lyophilized (32). For standard hyaluronidase determinations the lyophilized material was resuspended in 0.1 M acetate buffer, pH 3.8, containing 0.15 M NaCl.

Purification—A diethylaminoethylcellulose (DEAE, floc, Whatman) column (2.5 x 30 cm) was prepared and equilibrated with 0.05 M phosphate buffer, pH 7.0. The cellulose had previously been washed with 0.5 M NaCl and 0.5 M HCl and resuspended in 0.1 M sodium acetate containing 0.003 M EDTA. The acrosomal extracts were dissolved in 3 M of the phosphate buffer and applied to the column. The column was eluted using a stepwise NaCl gradient. A flow rate of 1 drop per 5 s was maintained.

Molecular Weight Estimation—A Sephades G-100 column 1 cm wide and 86 cm long was equilibrated with 0.1 M acetate buffer, pH 6.0, containing 0.15 M NaCl. Chromatography was performed at 5° maintaining a flow rate of 1 drop per 6 s. Bovine serum albumin (Armour), horseradish peroxidase (Worthington), pepsin (Worthington), and pancreatic trypsin (Worthington) were used as standards. Nine milligrams of bovine serum albumin and 5 mg of the other proteins were applied. The void volume was determined using dextran blue (Pharmacia Fine Chemicals). Twenty milligrams of lyophilized bovine acrosomal extract were dissolved in 1 ml of the acetate buffer and applied to the column. The molecular weight of hyaluronidase and of the acrosomal proteinase-proteinase inhibitor complex was determined by comparison with the standards according to the method of Whitaker (34).

Enzyme Properties—The pH optimum of acrosomal hyaluronidase was determined using 0.1 M acetate buffer containing 0.15 M NaCl. The pH of the enzyme and substrate solutions were adjusted using 0.01 M and 0.1 M NaOH or 0.01 M and 0.1 M HCl.

The stability of hyaluronidase under acidic conditions was evaluated by adjusting the pH of the enzyme solutions to 3.0 and incubating for 1 hour or 12 hours at 5°. The pH was subsequently readjusted to 3.5 and the solutions were tested for activity.

The temperature stability of hyaluronidase was determined by incubating the enzyme solutions in a water bath for 10 min at various temperatures. The tubes were cooled in tap water, and the hyaluronidase activity was determined. In addition, acrosomal hyaluronidase solutions were frozen and thawed eight times or kept at 5° for 30 days and the activity compared with the starting activity.

To determine whether salt was required for stability or activity, the enzyme solutions were either dialyzed against distilled H2O or 0.15 M NaCl for 24 hours at 5°. The activity of the dialyzed materials was determined, and the solutions were redialyzed against fresh H2O or 0.15 M NaCl for 24 hours. Hyaluronidase assays were performed at pH 3.8 in the absence or presence of NaCl.

The effect of FeCl2, FeCl3, MgSO4, MnSO4, CaCl2, ethylenediamine tetraacetate (EDTA, Fisher Chemical Co.), and heparin (Spencer Mead Co.) on acrosomal hyaluronidase was determined by incubating 0.1 ml of each in acetate buffer, pH 3.8, containing 0.15 M NaCl with 0.1 ml of enzyme in the same buffer for 15 min at 37° and performing a standard hyaluronidase assay. As a control, N-acetylhexosamine solutions were incubated with the compounds under the same conditions. Corrections were made if the compound affected the color formation.

Some of these properties were also determined for testicular hyaluronidase if they were not or only vaguely described in the literature.

Preparation of Antisera—Antibodies against rabbit and bull sperm acrosomal extracts were prepared by mixing the extracts (25 mg) with 2.3 ml of Freund's adjuvant using a tissue microhomogenizer and injecting the mixture subcutaneously into the inguinal and axillary regions. Rabbits were used for bull acrosomal extracts and guinea pigs were used for rabbit acrosomal extracts. After 3 weeks a booster injection of 5 mg of acrosomal extract was administered intraperitoneally every 2 days for 12 days. The animals were bled 10 days later. Bull testicular hyaluronidase antiserum was a generous gift from Dr. Truscheit, Research Laboratories, Farbenfabriken, Bayer AG (Wuppertal-Ellerfeld, Germany).

Immunochemical Techniques—Bull testicular and bull acrosomal hyaluronidase preparations were incubated with antiserum or normal rabbit sera as control at room temperature for 15 min before testing for activity using the colorimetric test. The solutions were centrifuged before measuring the absorbance since a
cloudy precipitate was frequently present. To determine the specificity of inhibition, rabbit sperm acrosomal hyaluronidase was incubated with bull acrosomal extract antisera. The inhibitory effect of antiserum on hyaluronidase activity was also evaluated using the immunoenzyme diffusion test (see below).

Regular immunodiffusion experiments were performed according to the method of Ouchterlony (35) using 1% agarose gel buffer with 0.1 M acetate buffer, pH 6.5. A new method was devised that allowed for the observation of both the immunoprecipitin bands and the enzyme activity. Agarose (1%) was mixed with 0.1% hyaluronic acid in 0.1 M acetate buffer, pH 6.5, containing 0.05 M NaCl, and immunodiffusion slides and Wilson plates (36) were prepared. After the precipitin bands had formed, the plates were submerged in 1% cetylpyridinium chloride dissolved in the same buffer. This resulted in a white precipitation of the hyaluronic acid, whereas the areas of hyaluronidase diffusion remained transparent.

RESULTS

Hyaluronidase Activity of Acrosomal Extracts—Acrosomal extracts in the absence of hyaluronic acid or hyaluronic acid in the absence of enzyme did not result in N-acetylhexosamine formation. Dott and Dingle (37) reported that β-glucuronidase may be present in the acrosomal extracts. This does not interfere with the assay since 2500 units of β-glucuronidase did not cause the release of N-acetylhexosamine when incubated with hyaluronic acid under the same conditions. Large differences exist among the hyaluronidase activities of the extracts of the species tested, decreasing in order from the ram, rabbit, bull, human, boar, rat, and stallion to rooster acrosomal extracts that did not possess any hyaluronidase activity (Table I). No significant differences in hyaluronidase activity could be found between the acrosomal extracts of epididymal and ejaculated sperm of the same species.

Purification of Rabbit and Bull Sperm Hyaluronidase—Both the bull and rabbit acrosomal hyaluronidase appeared in the first protein fraction after DEAE-cellulose column chromatography (Fig. 1). Respectively, a 27- and 25-fold increase in specific activity was obtained (Table II). Individual tubes possessed specific activities as high as 90 units per mg. The partially purified hyaluronidase preparations were used throughout the following experiments.

Optimum pH—The optimum pH of both bull and rabbit acrosomal hyaluronidase is 3.75 (Fig. 2). Activity ranged approximately from pH 3.0 to pH 7.0.

Stability—Neither bull nor rabbit acrosomal hyaluronidase activity was altered significantly by either freezing and thawing or refrigeration. Rabbit acrosomal hyaluronidase lost its ac-

### TABLE I

**Hyaluronidase activity of sperm acrosomal extracts from various species**

<table>
<thead>
<tr>
<th>Species</th>
<th>Origin</th>
<th>Specific activity (range)</th>
<th>Specific activity (average)</th>
<th>Number of pools or ejaculates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ram</td>
<td>Ejaculate</td>
<td>0.840–2.940</td>
<td>1.54</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Epididymide</td>
<td>0.610–1.840</td>
<td>1.22</td>
<td>3</td>
</tr>
<tr>
<td>Rabbit</td>
<td>Ejaculate</td>
<td>0.470–0.852</td>
<td>0.561</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Epididymide</td>
<td>0.600</td>
<td>0.600</td>
<td>1</td>
</tr>
<tr>
<td>Bull</td>
<td>Ejaculate</td>
<td>0.141–0.300</td>
<td>0.221</td>
<td>2</td>
</tr>
<tr>
<td>Human</td>
<td>Ejaculate</td>
<td>0.045–0.089</td>
<td>0.067</td>
<td>2</td>
</tr>
<tr>
<td>Boar</td>
<td>Ejaculate</td>
<td>0.016–0.086</td>
<td>0.015</td>
<td>13</td>
</tr>
<tr>
<td>Rat</td>
<td>Epididymide</td>
<td>0.009–0.032</td>
<td>0.029</td>
<td>8</td>
</tr>
<tr>
<td>Stallion</td>
<td>Ejaculate</td>
<td>0.014–0.015</td>
<td>0.016</td>
<td>3</td>
</tr>
<tr>
<td>Rooster</td>
<td>Ejaculate</td>
<td>0.000–0.030</td>
<td>0.004</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Epididymide</td>
<td>0.000–0.006</td>
<td>0.003</td>
<td>2</td>
</tr>
</tbody>
</table>

*Pooled before preparation of acrosomal extract (see text).*

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### FIG. 1

DEAE column chromatography of acrosomal extracts from ejaculated bull sperm. –––••••, absorbance at 280 nm; O—O, hyaluronidase activity. Lyophilized bull sperm acrosomal extracts (100 mg) in 3 ml of 0.05 M phosphate buffer, pH 7.0, were applied to the column and eluted with the same buffer using a stepwise salt gradient. A similar elution profile was obtained with rabbit sperm acrosomal extracts.

### FIG. 2

The pH optimum of bull and rabbit sperm acrosomal hyaluronidase. –––••••, bull sperm acrosomal hyaluronidase (30 μg); O—O, rabbit sperm acrosomal hyaluronidase (10 μg).
activity after 1 hour at pH 3.0. At this same pH, bull testicular and bull acrosomal hyaluronidase lost most of their activity in 1 hour and all activity in 12 hours.

Dialysis against H2O caused a significant decrease in bull sperm acrosomal hyaluronidase activity, the amount of decrease depending on the extent of dialysis. No activity was lost if bull sperm hyaluronidase was dialyzed against a solution of 0.15 M NaCl. The preparations dialyzed against H2O showed identical activities using substrate with or without NaCl, indicating that dialysis in the absence of salt permanently destroys the activity of the enzyme. Salt is also necessary for the hydrolysis of substrate since the absence of NaCl in the substrate solution resulted in a significant decrease in activity of preparations dialyzed in the presence of NaCl. Similar results were obtained with the rabbit acrosomal hyaluronidase preparations. Apparently salt is a requirement for both enzyme activity and enzyme stability.

Effect of Temperature—Bull and rabbit acrosomal hyaluronidase, as well as bull testicular hyaluronidase, lost most of their activity at 50° and all of their activity at temperatures above 60° (Fig. 3).

Effect of Ions, EDTA, and Heparin—Mg++, and Ca++ ions had no apparent effect on the activity of bull and rabbit acrosomal hyaluronidase, whereas Mn++ caused a slight decrease in activity at a concentration of 0.1 M. Fe+++ and Fe++ ions effectively decreased enzyme activity at 0.1 M and 0.01 M concentrations. Fe++ inhibited both bull and rabbit acrosomal hyaluronidase to a greater extent than Fe++. Care had to be taken to correct for the values obtained with Fe++, Fe+++, and Mn++. Since these ions affected the color formation by N-acetylglucosamine although never more than 20%. Bull acrosomal hyaluronidase was generally more effectively inhibited by metal ions than rabbit acrosomal hyaluronidase.

Even at concentrations of 0.5 M, EDTA had no effect on the activity of either bull or rabbit acrosomal hyaluronidase. Heparin (100 units) completely inhibited both bull (0.090 unit) and rabbit (0.100 unit) acrosomal hyaluronidase. EDTA and heparin had no effect on color formation by N-acetylglucosamine.

Molecular Weight Estimation—Judging from the elution pattern after Sephadex G-100 gel filtration, bull acrosomal hyaluronidase has a molecular weight of 110,000 (Fig. 4). This is approximately the same as the molecular weight of 126,000 reported for the dimeric form of bull testicular hyaluronidase (9). Similar to the proteinase-proteinase inhibitor complex present in boar sperm acrosomal extracts (31), data that will be published later show that such a complex is also present in bull sperm acrosomal extracts. This complex was eluted separately from the acrosomal hyaluronidase and possessed a molecular weight of 68,000.

Immunochemical Tests—Bull acrosomal extract antisera inhibited the activity of bull testicular and bull acrosomal hyaluronidase but not that of rabbit acrosomal hyaluronidase (Table III). Similarly, antisera against bull testicular hyaluronidase inhibited both acrosomal and testicular hyaluronidase. Normal rabbit sera did not affect the hyaluronidase activity. The same results were obtained using the immunoenzyme diffusion test (Fig. 5a). Ouchterlony plate tests showed that only one precipitin band is formed between bull testicular and bull acrosomal preparations and bull acrosomal extract antisera (Fig. 5b). This precipitin band showed a pattern of identity with one of the precipitin bands formed with crude or partially purified bull acrosomal hyaluronidase preparations. Using the immunoenzyme diffusion technique (Fig. 6) this precipitin band was identified as the complex formation between hyaluronidase and its antibody since the line of enzyme inhibition is identical with this band. No immunoprecipitin bands were formed between species.

<table>
<thead>
<tr>
<th>Source and amount of hyaluronidase</th>
<th>Control serum</th>
<th>Bull acrosomal extract antisera</th>
<th>Bull testicular hyaluronidase antisera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull acrosomes (35 μg)</td>
<td>0.120/100</td>
<td>0.019/16</td>
<td>0/0</td>
</tr>
<tr>
<td>Bull testicles (60 μg)</td>
<td>0.110/100</td>
<td>0.017/16</td>
<td>0/0</td>
</tr>
<tr>
<td>Rabbit acrosomes (7 μg)</td>
<td>0.115/100</td>
<td>0.120/100</td>
<td>0/0</td>
</tr>
</tbody>
</table>

Tests were performed as described in Table V. See text for further experimental details.
FIG. 5. a, effect of rabbit anti-bull acrosomal extract serum and normal rabbit serum on various hyaluronidase preparations in the immunoenzyme diffusion test. Hyaluronic acid (0.1%) was mixed with agarose (1%) in acetate buffer and immunodiffusion slides were prepared as described. After 16 hours of diffusion at 23°, submerging of the slides in 1% cetylpyridinium chloride dissolved in the same buffer resulted in a white precipitation of the unhydrolyzed hyaluronic acid, whereas the radial diffusion zones of the hyaluronidase appeared transparent. The area of complex formation between hyaluronidase and its antibody can be seen as a distinct zone of enzyme inhibition, whereas the diffusion of rabbit acrosomal hyaluronidase proceeds without inhibition. b, agar gel immunodiffusion test of bull testicular hyaluronidase preparations and bull acrosomal extracts versus rabbit anti-bull acrosomal extract serum. Precipitin band p is identical between the preparations. The other bands derive only from the acrosomal extracts. Due to the large excess and higher diffusion rate, one of these bands almost completely surrounds the central well. Similarly, an identical precipitin band was present using bull sperm acrosomal hyaluronidase partially purified by DEAE column chromatography as antigen instead of bull acrosomal extracts. Such a band was also formed using anti-bull testicular hyaluronidase serum instead of anti-bull acrosomal extract serum. No precipitin bands were formed between rabbit acrosomal hyaluronidase preparations and bull testicular or bull acrosomal extract antisera. BAE, bull acrosomal extracts (20 mg per ml); BTH, bull testicular hyaluronidase (10 mg per ml); BTH₁, bull testicular hyaluronidase (20 mg per ml); RAE, rabbit acrosomal extracts (20 mg per ml); A, anti-bull acrosomal extract serum; N, normal rabbit serum.

DISCUSSION

Two types of hyaluronidases have been reported to occur in mammals: (a) lysosomal hyaluronidase that is found, for example, in the liver, kidney, bone marrow, and serum; and (b) testicular hyaluronidase. Lysosomal hyaluronidase has an optimum pH of 3.5 and is not active above pH 4.5 (7), whereas acrosomal hyaluronidase has its optimum activity at pH 3.75 and has activity over a much wider pH range. In addition, lysosomal hyaluronidase does not require salt for activity (7). Acrosomal hyaluronidase therefore differs from lysosomal hyaluronidase. Although the acrosome is considered to be a lysosome (38), we now know that at least two of the acrosomal enzymes, hyaluronidase and the acrosomal proteinase (30), have characteristics that are different from similar enzymes usually found in lysosomes, emphasizing the uniqueness of the sperm as a cell.

The biochemical properties of acrosomal hyaluronidase described in this communication correspond to those reported for testicular hyaluronidase (7, 8, 30, 40) with one exception. Meyer and Rapport (39) showed that Fe⁺⁺⁺ is a more effective inhibitor for testicular hyaluronidase than Fe⁺⁺⁺. Although this is in contrast to the relative effect of these ions on acrosomal hyaluronidase, it is probably due to the different assay method.
used or to the rather long incubation time of enzyme with substrate in the present test.

Bull testicular hyaluronidase antisera and bull acrosomal extract antisera show cross inhibitory activity in the colorimetric enzyme assay experiment. In the immunodiffusion test, one precipitin line between acrosomal extract and its antisera shows a pattern of identity with the only precipitin band between testicular hyaluronidase and this antisera. In the combined immunoelectrophoresis and coimmunoprecipitation test, these precipitin lines delineate clearly the zone of hyaluronidase inhibition. Based on these observations, there seems to be little doubt that testicular and sperm acrosomal hyaluronidase display the same immunological properties. Rabbit sperm acrosomal hyaluronidase is neither precipitated nor inhibited by antisera against bull sperm acrosomal extract produced in rabbits, indicating significant differences in antigenicity of the heterologous bull acrosomal hyaluronidase and the isologous rabbit acrosomal hyaluronidase.

Lysosomal and testicular (acrosomal) hyaluronidase differ biochemically (1, 2, 7); however, differences in immunological characteristics remain to be determined. In case testicular (acrosomal) hyaluronidase could be identified as specific for spermatozoa, it is indeed conceivable that the isoimmunization of females with testicular hyaluronidase results in impaired fertility without affecting other cells, provided the antibodies enter into the Fallopian tube fluid.

The pH optimum of rabbit and bull acrosomal hyaluronidase is similar to that of human sperm hyaluronidase (4) although a much wider range of optimal activity was obtained with the human enzyme. This is most likely due to the impurity of the human sperm preparation tested since pH experiments with unpurified rabbit acrosomal extracts produced a similar wide pH optimum. The relative hyaluronidase activities of the acrosomal extracts of the species tested correlate with those reported for whole sperm (41). Srivastava et al. (14) reported a somewhat higher hyaluronidase activity in bull than in rabbit acrosomal extracts. This difference can be explained since in the present study the bull semen was obtained frozen and had to be thawed causing hyaluronidase release into surrounding plasma and therefore a decrease in the specific hyaluronidase activity of the acrosomal extracts.

Stanbaugh and Buekley (42) reported that the zona penetrating enzymes of rabbit spermatozoa occur as a single complex of hyaluronidase and a protease with a combined molecular weight of 59,000. These authors based their conclusion on a sucrose density gradient centrifugation experiment involving crude rabbit extracts that had been obtained by sonication of whole sperm. The present results show that bull sperm acrosomal hyaluronidase and protease appear in separate fractions after Sephadex G-100 column chromatography, indicating that at least in this species the enzymes are most likely not in complex.

Sperm acrosomes possess β-glucuronidase as well as N-acetyl-glucosaminidase (37, 38). The function of these enzymes in the fertilization process is still unknown. Similar enzymes are present in lysosomes. Since hyaluronidase produces only tetrasaccharides on hydrolysis of hyaluronic acid (8), it is generally assumed that in the case of lysosomes β-glucuronidase breaks these oligosaccharides further down to disaccharides which in turn are hydrolyzed to monosaccharides by N-acetylglucosaminidase (5). It seems likely that a similar process occurs when sperm hydrolyze the hyaluronic acid moeity of the cumulus and that it may be a combined action of all three enzymes that aids sperm in the penetration through the cumulus oophorus.

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Addendum—Since the submittal and acceptance of this article, data were published by Metz et al. (43, 44) showing that hetero- and iso-antibodies produced against epididymal and ejaculated rabbit semen prevented the dispersion of the cumulus oophorus or hydrolysis of hyaluronic acid by epididymal, ejaculated, and capacitated rabbit semen or rabbit sperm extracts. Similar results were obtained with human material. Reactions were completely species specific. Castro and Metz (45) also demonstrated differences in antibody inhibition between human sperm hyaluronidase and human serum (lyso- somal) hyaluronidase, emphasizing the dissimilarity of these enzymes.

REFERENCES

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