THE TAURINE CONCENTRATION OF ORGANS FROM FED AND FASTED RATS*

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Taurine exists free in the organs of many animals (1–4) and also in combined form, as in the bile salts. The composition of bile salts from over 100 animal species was recently reported, and taurine was the most commonly occurring conjugate (5). The large amount of taurine present in certain tissues seems to be in excess of the amount needed for the formation of bile salts. Moreover, taurine is found in organs of animals such as the rabbit (5), that do not produce taurine-containing bile salts, and it is also formed from inorganic sulfate in the chick embryo (6, 7). From these facts it may be inferred that taurine may play some other rôle besides that of forming bile salts. Considerably more information than that now available is needed to understand the rôle of taurine. In the present work attention has been directed to the taurine concentration of tissues, including the effect of fasting, of starvation, and of the endocrine glands. In addition, the amounts of taurine excreted in the urine have been measured after the administration of cysteine. From the results obtained, it is concluded that taurine is formed even when animals are fasted and that the levels of taurine in most organs do not change to any great extent. Some unexpected sex differences in the taurine concentration of liver were observed in the rat.

EXPERIMENTAL

The determination of taurine was carried out in extracts prepared according to a method described previously (8). The aqueous extracts thus obtained are passed through a 4 × 1 cm. column of Dowex 50-X8 (200 to 400 mesh) in the acid form; 5 cc. of eluate were collected. All of the taurine is found in the eluate, with little contamination from other ninhydrin-reacting substances; when cysteic acid is present, small amounts appear in the eluate. For this reason the eluate is evaporated to dryness in the steam bath and then taken up in 1 cc. of water; 50 µl. of this solution are applied to filter

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TAURINE CONCENTRATION OF ORGANS

paper, neutralized with ammonia vapors, and chromatographed with 2,4-lutidine. The extracts of most organs gave a single compact spot which was easily measured quantitatively by any of the known procedures. The elution method with the ninhydrin reagent of Moore and Stein (9) was preferred. This method is reproducible within 10 per cent, and the recovery from the tissues is about 90 per cent. Taurine was determined in measured portions of urine by simply passing the urine through a column of Dowex 50, as described above. The urine was first centrifuged and, if necessary, concentrated to a smaller volume on the steam bath.

Rats of the Sprague-Dawley strain, weighing 200 to 250 gm., were used. The animals were fed Purina chow when not on a special diet. They were sacrificed by decapitation, and samples of the organs to be studied were extracted immediately. Organs from beef, pig, and sheep were obtained from the slaughter-house and put on dry ice within a few minutes after removal.

Hypophysectomized rats were obtained commercially. Gonadectomies and adrenalectomies were performed by the usual procedures. The gonadectomized animals were sacrificed 3 weeks and the adrenalectomized animals 2 weeks after the operation. During this time, they were given salt in their drinking water. A group of gonadectomized male rats received estrogen (estradiol dipropionate, Schering) in doses of 10 \( \gamma \) per day per rat for 10 days. Cysteine was administered by stomach tube. Food was available except in an 8 hour period during which the rats were placed in metabolic cages for the collection of urine.

Results

Taurine Concentration in Organs from Fed Animals—In Tables I and II are recorded the amounts of taurine found in organs from the fed and fasted rat, rabbit, guinea pig, beef, pig, and sheep. Taurine was not found in the liver of the rabbit or guinea pig, even though as little as 0.2 \( \mu \)mole per gm. of tissue could be detected by the method. In nearly all instances more taurine was present in the organs of the rat than in corresponding tissues of the rabbit or guinea pig. It is interesting that in the rabbit the taurine concentration in heart was 15 \( \mu \) moles per gm., whereas there was no detectable taurine in the liver. As mentioned before, the rabbit produces bile salts containing glycine exclusively (5). Neither taurine nor 2-aminoethanesulfonic acid was detected in the liver of the rabbit after the injection of cysteine (unpublished experiments). In the rat heart, taurine was found in large quantities; indeed, in the male rat, the taurine concentration in the heart was 17 times greater than in the liver. In the female rat, this ratio was much smaller, because the taurine concentration in liver was greater, an unexpected sex difference apparently not controlled ex-
### TABLE I

**Taurine Content of Rat Organs from Fed and Fasted Rats**

Values, in micromoles per gm. of fresh tissue, are averages from six animals, ± the standard error of the mean.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fed</td>
<td>16 hr. fast</td>
</tr>
<tr>
<td>Liver</td>
<td>1.6</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>±0.2</td>
<td>±0.5</td>
</tr>
<tr>
<td>Kidney</td>
<td>7.4</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>±0.6</td>
<td>±0.4</td>
</tr>
<tr>
<td>Spleen</td>
<td>11.0</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td>±0.4</td>
<td>±1.0</td>
</tr>
<tr>
<td>Heart</td>
<td>28.4</td>
<td>27.9</td>
</tr>
<tr>
<td></td>
<td>±10.5</td>
<td>±0.9</td>
</tr>
<tr>
<td>Brain</td>
<td>5.5</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>±0.3</td>
<td>±0.2</td>
</tr>
<tr>
<td>Small intestine</td>
<td>10.9</td>
<td>10.6</td>
</tr>
<tr>
<td>Muscle</td>
<td>9.4</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>±1.1</td>
<td>±2.6</td>
</tr>
<tr>
<td>Testis</td>
<td>2.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Uterus</td>
<td>±0.3</td>
<td>±0.1</td>
</tr>
</tbody>
</table>

### TABLE II

**Taurine Content of Some Organs from Guinea Pig, Rabbit, Pig, Beef, and Sheep**

Values in micromoles per gm. of fresh tissue.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Guinea pig*</th>
<th>Rabbit*</th>
<th>Pig</th>
<th>Beef</th>
<th>Sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Liver</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Kidney</td>
<td>1.8</td>
<td>1.0</td>
<td>1.9</td>
<td>2.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Spleen</td>
<td>5.6</td>
<td>5.2</td>
<td>5.7</td>
<td>5.6</td>
<td>5.1</td>
</tr>
<tr>
<td>Heart</td>
<td>9.3</td>
<td>12.3</td>
<td>14.6</td>
<td>15.8</td>
<td>33.7</td>
</tr>
<tr>
<td>Brain</td>
<td>1.0</td>
<td>0.6</td>
<td>1.1</td>
<td>1.8</td>
<td>†</td>
</tr>
<tr>
<td>Small intestine</td>
<td>3.8</td>
<td>2.3</td>
<td>4.2</td>
<td>2.9</td>
<td>†</td>
</tr>
<tr>
<td>Muscle</td>
<td>9.1</td>
<td>9.2</td>
<td>1.3</td>
<td>3.7</td>
<td>10.4</td>
</tr>
<tr>
<td>Testis</td>
<td>0.9</td>
<td>0.7</td>
<td>3.5</td>
<td>1.6</td>
<td>†</td>
</tr>
<tr>
<td>Uterus</td>
<td>3.5</td>
<td>1.6</td>
<td>1.8</td>
<td>1.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Pancreas</td>
<td>†</td>
<td>†</td>
<td>†</td>
<td>†</td>
<td>†</td>
</tr>
</tbody>
</table>

* Average of values from two animals.
† Not determined.
clusively by sex hormones. Other differences were noted in the taurine content of liver from other species and also in the heart. Relatively low

**Table III**

**Endocrine Regulation of Taurine Concentration in Some Organs of Rat**

The values, in micromoles per gm. of fresh tissue, are averages from six animals, ± the standard error of the mean.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hypophysectomy</td>
<td>Adrenalectomy</td>
<td>Castration</td>
<td>Estrogen</td>
</tr>
<tr>
<td>Liver</td>
<td>1.7 ± 0.3</td>
<td>1.7 ± 0.2</td>
<td>1.6 ± 0.1</td>
<td>2.1 ± 0.4</td>
</tr>
<tr>
<td>Kidney</td>
<td>9.6 ± 0.3</td>
<td>6.7 ± 0.4</td>
<td>8.2 ± 0.3</td>
<td>8.3 ± 0.4</td>
</tr>
<tr>
<td>Spleen</td>
<td>15.3 ± 0.6</td>
<td>11.8 ± 0.8</td>
<td>13.8 ± 0.5</td>
<td>12.6 ± 0.4</td>
</tr>
<tr>
<td>Heart</td>
<td>24.3 ± 0.8</td>
<td>28.0 ± 1.1</td>
<td>27.2 ± 0.9</td>
<td>27.1 ± 1.4</td>
</tr>
<tr>
<td>Muscle</td>
<td>17.0 ± 0.9</td>
<td>13.3 ± 0.3</td>
<td>11.6 ± 1.3</td>
<td>12.7 ± 0.6</td>
</tr>
</tbody>
</table>

**Table IV**

**Taurine Excretion by Rat**

Values in micromoles per 24 hours.

<table>
<thead>
<tr>
<th>Rat No.</th>
<th>Control period, 24 hrs.</th>
<th>After cystine,* 24 hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47</td>
<td>225</td>
</tr>
<tr>
<td>2</td>
<td>72</td>
<td>245</td>
</tr>
<tr>
<td>3</td>
<td>69</td>
<td>266</td>
</tr>
<tr>
<td>4</td>
<td>53</td>
<td>215</td>
</tr>
<tr>
<td>5</td>
<td>57</td>
<td>180</td>
</tr>
<tr>
<td>6</td>
<td>76</td>
<td>195</td>
</tr>
</tbody>
</table>

Average ................. 62 221

* 100 mg. by stomach tube.

values for the taurine concentration of heart from beef and sheep were found when compared with heart from rodents or pig.

**Effect of Fasting**—In Table I values for the taurine concentration of organs from rats fasted 16 hours and for 7 days are presented. In both instances the taurine concentration of liver changed significantly and, during the 7 day fast, the increase in liver and in skeletal muscle was marked in male rats. These results are in agreement with those reported by Wu
who found a large increase in the taurine content of both liver and skeletal muscle from male rats after 9 days of fasting. In contrast, the concentration of taurine in the liver of female rats was greatly decreased after a 7 day fast. The other organs changed very little, and in most cases the differences were not statistically significant.

Endocrine Regulation—Sex differences in the taurine content of liver and the contrasting effect of fasting prompted the additional studies listed in Table III. None of the procedures affected the taurine content of the liver of male rats, but hypophysectomy caused an increase in spleen, kidney, and, particularly, in skeletal muscle. The effect of adrenalectomy on the taurine content of skeletal muscle was statistically significant but less marked. Gonadectomy and the treatment of gonadectomized or of intact males with estrogens were ineffective. Adrenalectomy and gonadectomy brought about a significant reduction in the taurine content of the liver of female rats.

Urinary Excretion of Taurine—Table IV presents values for taurine excretion by male rats, calculated on a 24 hour basis. Table IV also contains values for the urinary excretion of taurine after feeding 100 mg. of cysteine by stomach tube. The increase after feeding cysteine was significant but represented only 20 per cent of the total cysteine fed.

DISCUSSION

With few exceptions taurine was found in every organ studied and in concentrations which remained fairly constant, even when the animals were subjected to long periods of fasting. Taurine is excreted almost quantitatively in the urine when administered by mouth or intravenously (11, 12). This apparent stability of taurine in the body was not confirmed by Eldjarn (13) who administered S35-labeled taurine to a human subject and was unable to recover all of the activity in the urine.

Taurine is formed from cystine, cysteine, or indirectly from methionine. The immediate precursor of taurine is 2-aminoethanesulfonic acid (14, 15) which is formed from cysteinesulfonic acid by decarboxylation (16). Hope (17) recently reported data which strongly suggest that cysteic acid decarboxylase could be, in effect, cysteinesulfonic acid decarboxylase. It is of interest that Sloan-Stanley (18) and also Hope (17) found sex differences in the ability of liver to decarboxylate cysteic acid and cysteinesulfonic acid. They reported that the liver of male rats had greater decarboxylating activity than that of female rats, an effect opposite to what might be expected from the results of this study. The amount of taurine observed in organs such as the heart and spleen suggests that these organs concentrate taurine against a high concentration gradient. This is particularly true in the rabbit in which the taurine concentration in the liver is below the limits of
detection by our methods. Portman and Mann (19) recently reported that the urinary excretion of administered taurine-S\textsuperscript{35} is less in rats previously fed a low sulfur diet than in rats fed a high sulfur diet. They also found a high level of S\textsuperscript{35} in tissues 24 hours after the administration of taurine-S\textsuperscript{35}. These levels were higher in the organs of rats fed a diet low in organic sulfur. From these results and ours, it is concluded that taurine plays other roles in addition to the only one known, namely the formation of bile salts.

**SUMMARY**

The taurine concentration of several organs from the rat, rabbit, guinea pig, beef, pig, and sheep has been measured. Sex differences were observed in the taurine concentration of the liver of the rat. The effect of fasting, adrenalectomy, hypophysectomy, gonadectomy, and estrogen treatment on the taurine concentration of several organs was studied. Only in a few instances were changes in the concentration of taurine observed. The taurine excretion by the rat was increased after administration of cysteine.

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**BIBLIOGRAPHY**

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