THE EFFECT OF STARVATION ON THE CATALASE CONTENT OF TISSUES

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When an animal is starved or is supplied with an insufficient amount of food to meet the wear and tear and energy requirements of the body, the tissues themselves are consumed. The extent of this consumption differs very widely in the different organs. The heart for example, loses very little in weight while the skeletal muscles lose much, the fat and glycogen completely disappear. The organs in which metabolism is most

intense, such as the heart and central nervous system, preserve themselves best while the organs in which metabolism is less intense waste away. The preservation of the working tissues is thought to be brought about by the autolysis of the other less active tissues. The products of autolysis of these less active tissues pass into solution in the blood, are carried to the master tissues and used. The object of this investigation was to determine what change, if any, occurs in the catalase content of the heart, skeletal muscles and fat during starvation with the hope of finding an explanation for the fact that the heart muscle is not autolyzed during starvation while the skeletal muscles and fat are.

Twelve rabbits were placed in a cage and fed for six days on cabbage, turnips and apples. At the end of this time two of the rabbits were etherized and the blood vessels washed free of blood by the use of large quantities of 0.9 per cent sodium chloride. The heart, soleus muscle (red muscle) and fat around the kidney were removed and ground up separately in a hashing machine. The catalase content of these tissues was determined by adding one gram of the material to 45 cc. of hydrogen peroxide in a bottle. As the oxygen gas was liberated it was conducted through a rubber tube into an inverted burette previously filled with water. After the oxygen gas thus collected was reduced to standard atmospheric pressure the resulting volume was taken as a measure of the amount of catalase in one gram of the tissue. The catalase content of the heart, soleus muscle and fat of rabbits starved for two, four and six days respectively was determined as it had been for the normal rabbits. The results of these determinations are given in table 1. Each of the determinations represents an average for two animals.

TABLE 1.

After heart, leg and fat are given the amounts of oxygen in cubic centimeters, liberated in ten minutes from 45 cc. of hydrogen peroxide by the catalase in 1 gram of the respective muscles of rabbits.

Rabbits	Normal	Starved Two days	Starved Four days	Starved Six days
Fat	33	13	12	No fat
Heart	73	71	75	75
Leg	72	58	54	44

It may be seen in table 1 that one gram of the heart muscle of the normal rabbit liberated 73 cc. of oxygen in ten minutes

from 45 cc. of hydrogen peroxide; that of the rabbits starved for two, four and six days liberated 71, 75 and 75 cc. of oxygen respectively; that 1 gram of the leg muscle of the normal rabbit liberated 72 cc. of oxygen; that of the rabbits starved for two, four and six days liberated 58, 54 and 44 cc of oxygen respectively; that one gram of the fat of the normal animals liberated 33 cc of oxygen, that of the animals starved for two and four days liberated 13 and 12 cc. of oxygen respectively while there was not sufficient fat in the animals starved six days for a determination.

By comparing the amounts of oxygen liberated by the heart of the animals starved for the different lengths of time, it will be seen that starvation produced no effect on the catalase content of the heart muscle, that it reduced the catalase content of the leg muscle by 37 per cent as is indicated by the decrease from 72 cc. of oxygen, the amount liberated by 1 gram of the muscle of the normal animals to 44 cc., the amount liberated by the muscle of the animals starved for six days. It may also be seen that the catalase content of the fat was reduced during the first two days of starvation by about 61 per cent as is indicated by the reduction of oxygen liberated from 33 cc., the amount liberated by one gram of fat of the normal animal to 13 cc., the amount liberated by one gram of fat of the animal starved for two days, and that the catalase content of the fat remained low during the rest of the period of starvation.

The preceding experiments show that the catalase content of fat and skeletal muscles which are autolyzed during starvation is decreased while it remains normal in amount in the heart which is not autolyzed during starvation. It has been shown that the amount of oxidation in a tissue is proportional to the amount of catalase present (1). From this it follows that oxidation is decreased during starvation in tissues such as fat and skeletal muscles in which the catalase is decreased, and remains normally high in a tissue such as the heart muscle. It is known that the autolyzing enzymes in common with other enzymes are destroyed by oxidation (2). The great resistance of the heart muscle to the digestive action of the autolyzing enzymes during starvation may be due to the intense oxidation in this organ, the assumption being that the autolyzing enzymes are oxidized and thus rendered inert. By the great decrease

in the oxidative processes of skeletal muscles and fat during starvation the check on the autolyzing enzymes is removed and they are thus left free to digest these tissues.

Conradi (3), Rettger (4), and Effront (5) showed that when bacteria and yeasts were starved by being placed in a physiological salt solution, where there was no food, they were autolyzed. The explanation usually offered this bacterial autolysis is that "the normal existing autolytic processes are not counteracted by synthesis of new protein material." A more plausible explanation would seem to be that by starvation the oxidative processes are decreased, thus removing the normal check on the autolytic enzymes, with resulting digestion of the cells.

Neuberg (6) found that when cancer tissue was exposed to radium rays the rate of autolysis of this tissue was greatly increased. He also found that the autolyzing enzymes of this tissue were not destroyed as were the oxidizing and other enzymes by the exposure. On the basis of these experiments it is assumed that the great increase observed in the activity of the autolyzing enzymes in the cancer tissue when exposed to radium rays was made possible by the decrease in oxidation in this tissue which in turn was due to the destruction of the oxidizing enzymes by the rays, thus leaving the autolyzing enzymes free to digest the cancer tissue.

It has been shown that the resistance to the digestive action of trypsin of unicellular organisms, paramecia, living in a solution of this enzyme can be decreased by decreasing the oxidative processes so that these organisms are literally digested alive and that they are revived provided digestion has not proceeded too far, when normal oxidation is restored (7). From these and similar experiments (8) the authors conclude that the means by which living cells protect themselves from being digested by intracellular as well as extracellular enzymes is oxidation.

CONCLUSIONS

From the evidence presented in this paper the conclusion is drawn that the catalase content of the heart, which is not autolyzed during starvation, remains normally high while the catalase content of the fat and skeletal muscles, which are auto-

lyzed during starvation, is greatly decreased. In view of the fact that the catalase content of a muscle is directly proportional to the amount of oxidation in the muscle and that the autolyzing enzymes are destroyed by oxidation, the further conclusion is drawn that the heart is not autolyzed during starvation because oxidation in this organ remains normally intense and thus provides for this oxidation of the autolyzing enzymes and the maintenance of the normal balance between oxidation and autolysis; on the other hand the fat and skeletal muscles are autolyzed during starvation because of the decreased oxidation which leaves the autolytic enzymes free to digest these tissues.

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