Glycerol Ester Hydrolase Activity of Microbacterium thermosphactum

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Microbacterium thermosphactum possesses a significant glycerol ester hydrolase (lipase, EC 3.1.1.3) activity and a weak but definite carboxylic ester hydrolase (esterase, EC 3.1.1.1) activity. Harvested whole cell preparations contained 53 units of lipase activity with tripropionin as the substrate. This activity decreased with an increasing chain length of fatty acid in the triglyceride to 13 units with trilaurin as the substrate and no activity with tripalmitin. Maximum lipase activity was found at a temperature of 35 to 37 °C and at a pH of 7.1 to 7.3. Lipase activity was associated with three different protein peaks when the protein of cell-free extract was fractionated by polyacrylamide gel electrophoresis.

In 1953, McLean and Sulzbacher (8) identified Microbacterium thermosphactum as the organism repeatedly isolated from and associated with pork sausage flavor deterioration. This organism has since been thoroughly documented as a common isolate from fresh and spoiled meats (2, 3, 16, 20). Microbial lipase activity is frequently responsible for not only off-flavor development and definite spoilage in meats but also for the relatively subtle flavor changes characteristic of certain aged meats (1). Despite the possible participation of Microbacterium thermosphactum lipase in the flavor change in meats, the lipolytic activity of this bacterium has not yet been investigated and related literature was not very helpful in predicting the outcome. Other species of Microbacterium examined by Nashif and Nelson (11) were nonlipolytic, whereas some coryneform bacteria, apparently closely related to Microbacterium thermosphactum, tested by Jayne-Williams and Skerman (6) were lipolytic with butterfat. The purpose of this investigation was to show that Microbacterium thermosphactum possesses a glycerol ester hydrolase (EC 3.1.1.3) which forms monocarboxylic acids from triglycerides as a substrate and to characterize partially this enzyme.

MATERIALS AND METHODS

The strain of Microbacterium thermosphactum used was isolated from beef and identified by comparison tests with a known strain. Stock cultures were prepared by inoculating Trypticase soy broth (TSB) with freshly grown culture (1% inoculum) and then freezing and storing the inoculated broth at −20 °C. These cultures were used to inoculate fresh broth as needed.

The objectives of the following methods were to determine the ability of Microbacterium thermosphactum to hydrolyze triglycerides in emulsion (lipase activity) and in solution (esterase activity). The methods were also designed to locate the protein bands which show lipase activity on polyacrylamide gel electrophoresis and to relate temperature, pH, and substrate specificity to the glycerol ester hydrolase activity.

Preparation of cells and cell-free extracts. Cells grown in TSB at 22 °C were harvested by centrifugation at 2 °C, washed twice with 0.01 M tris(hydroxymethyl)-aminomethane (Tris) buffer, pH 7.2, and resuspended in the same buffer. Cell-free extracts were prepared by the disruption of the cells by one passage through a French pressure cell at 8,000 psi. The cell debris was removed by centrifugation at 15,000 × g for 30 min at 2 °C. The protein content of whole cells and that of cell-free extracts were determined by the biuret method (17). Crystalline serum albumin was used for the standard curve.

Esterase activity. The esterase activity of a cell suspension was determined by titration of the liberated acids with an automatic recording pH-stat (E. H. Sargent and Co., Chicago, Ill.). The initial velocity of the hydrolysis of the substrate was followed by continuous titration. The reaction mixture of an aqueous solution of triacetin or methyl butyrate was assayed at 35 °C. The mixture was maintained at pH 7.2 by continuous addition of 0.01 N CO2-free KOH. Blanks containing boiled enzyme and the substrate alone were similarly treated.

Lipase activity. The lipolytic activity of Microbacterium thermosphactum cells or cell-free extracts was also determined by the continuous pH-stat method. The different substrates were emulsified with 10% gum arabic as described by Desmuelle et al. (5) by using ultrasonic treatment. The mixture was sonically treated with a Branson Sonifier (model SI25) by using full power for 2 min. During emulsification, the mixture was placed in an ice bath to prevent breakdown of the substrates.
TABLE 1. Lipase activity of whole cells and fractions of Microbacterium thermodspactum measured by the pH-stat procedure with tripropionin as the substrate

| Fraction                  | Lipase activity (units) |
|---------------------------|-------------------------|
| Whole cells               | 53                      |
| Broken cells              | 40                      |
| Cell-free extract         | 40                      |
| Cell debris               | 0                       |
| Growth medium supernatant | 20*                     |

* Activity expressed as units per milliliter of medium.

Blanks containing the boiled enzyme, substrate without enzyme, and enzyme alone were similarly titrated. In initial studies, the agar-well technique (14) was used to screen for possible substrates. Plain unbuffered 1% agar gels were used. Zones of hydrolysis were noted after 24 hr of incubation at 30 C.

For both esterase and lipase, 1 unit of activity is defined as that amount of enzyme catalyzing the formation of one nano-equivalent of acid per minute per milligram of protein.

Polycrylamide gel electrophoresis. A system was developed on the basis of the principles of Ornstein (13) and of Davis (4) for the detection of glycerol ester hydrolase activity in electrophoretically separated protein components of bacterial extracts. Disc gel electrophoresis was carried out on 6% polyacrylamide gel (pH 8.5) at 4 C with a current of 3.5 ma per 6.5-mm plexiglass tube for 2 hr on a Canalco model 6 electrophoresis gel. Gel containing 6% acrylamide, 0.3% bis-acrylamide (N,N'-methylenbisacrylamide; Canalco, Inc.), 0.0008% N,N',N',N'-tetramethylethylendiamine (Canalco, Inc.), and 0.0008% ammonium persulfate (Fischer Scientific) was made in 0.1 M Tris-hydrochloride buffer, pH 8.5. The bath buffer was 0.04 M phosphate buffer, pH 7.2. Gels were allowed to solidify for 30 min before use, and no spacer or stacking gel was used. The gels were stained for 45 min in 7% glacial acetic acid containing 0.5% aniline black. Destaining was done by repeated washing in 7% glacial acetic acid on a shaker.

After development and staining, the gels were scanned by using a Gilford gel scanning attachment to a Beckman DU spectrophotometer converted with a photomultiplier apparatus attached to a Sargent model SR recorder. Scan speed was 4 cm/min with the recorder set on 5 inches/min.

Lipase detection in gels. Developed polycrylamide gels were cut in the frozen state by use of razor blades taped in a pile to yield slices of 1.2 mm in thickness. These were layered separately on the agar of plates prepared by the agar-well technique described above. Lipase activity was observed as clearing zones around gels in 48 hr.

RESULTS AND DISCUSSION

A preliminary demonstration of the lipolytic activity of Microbacterium thermodspactum was made by using the agar-well technique. Clear, wide zones were formed with tripropionin or tributyrin as the substrate, a definite but smaller clear zone was formed with triacetin, and no clear zone was formed with tricaprin, tricaprylin, trilaurin, and tripalmitin. Identical results were obtained

TABLE 2. Substrate specificity of the lipase from whole cells of Microbacterium thermodspactum measured by the pH-stat procedure

| Substrate   | Lipase activities (units) |
|-------------|--------------------------|
| Tripropionin| 53                       |
| Tributyrin  | 40                       |
| Tricaprin   | 40                       |
| Tricaprylin | 20                       |
| Trilaurin   | 13                       |
| Tripalmitin | 0                        |

* Total volume of 6 ml of the reaction mixture contained 60 mmoles of substrate sonically dispersed in 10% gum arabic and 1 ml of whole cells of M. thermodspactum at a final pH of 7.2.
with both whole cells and cell-free extracts. These findings were sufficiently encouraging to suggest the use of the more sensitive and dependable pH-stat method of measuring glycerol ester hydrolase (lipase) activity.

The lipolytic activities on tripropionin of whole cells, cell fractions, and the growth medium supernatant of _M. thermosphactum_ by using the pH-stat method are given in Table 1. Although no attempt was made to define carefully the enzyme location, the lipase appears to be both extracellular and intracellular. It was unlikely that the rather high extracellular activity resulted from the artifact of cell death and autolysis, because the cultures used were harvested during the exponential growth phase. Since whole cells showed the highest activity, they were used in all subsequent experiments.

The substrate specificity of _M. thermosphactum_ lipase was again determined by using the pH-stat method, and the results are given in Table 2. This more sensitive method extended the substrate specificity of _M. thermosphactum_ lipase to include tricaprin, tricaprylin, and trilaurin but still showed no activity towards tripalmitin. This lipase appears to catalyze preferentially the hydrolysis of short-chain fatty acid triglycerides, and the activity is progressively reduced with increased chain length.

The temperature-activity and pH-activity profiles of the lipase of _M. thermosphactum_ whole cells by using tripropionin as the substrate are given in Fig. 1 and Fig. 2, respectively. Maximum lipase activity was found at 35 to 37°C and at pH 7.1 to 7.3. These values correspond to those found for lipases from other microorganisms, despite the use of a wide variety of assay methods and substrates. The majority of microbial lipase show an optimum temperature within the range of 35 to 40°C (7, 10, 12, 18) and an optimum pH within the range from 7.0 to 7.8 (10, 15, 18, 19).

The ability of whole cells of _M. thermosphactum_ to hydrolyze ester bonds in solution (esterase activity) was definite but weak. The esterase activity was 16 units with triacetin as the substrate and 10 units with methyl butyrate as the substrate. Both substrates were at a concentration of 10 mM/ml, which was well below their limit of solubility and excluded lipase activity being confused with esterase activity as a result of hydrolysis of these substrates at concentrations exceeding their solubility.

The separation of the protein in cell-free extracts of _M. thermosphactum_ by polyacrylamide gel electrophoresis is shown in Fig. 3. Lipase activity was found associated with the protein peaks located at migration distances of 1.2, 2.2, and 4.8 cm. Separable bands of lipase activity have been previously observed as discussed by Mencher and Alford (9), who also resolved the purified lipase of _Pseudomonas fragi_ into two distinct peaks by electrophoresis and by sucrose density gradient centrifugation. No conclusion could be drawn as to whether the three separate lipase fractions found in our study were true isoenzymes or merely a single lipase species complexed with other components of the cell, but they were consistent and reproducible.
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