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Exploration of Thermophilic Bacteria: Systematic Literature Review

Gustina Indriati[1], Ruth Rize Paas Megahati S[2*]

1Study Programs of Hyperkes and Occupational Safety, Sekolah Tinggi Ilmu Kesehatan Indonesia, Padang, Indonesia
[2]Medical Laboratory Engineering Study Program, Politeknik Kesehatan Kesuma Bangsa, Bandar Lampung, Indonesia

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Corresponding Author:
Ruth Rize Paas Megahati S
megahatis23@gmail.com

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Abstract: The selection of enzymes derived from microbes has several advantages compared to those derived from animals and plants. One of the advantages is that the growth of enzymes will occur more quickly in bacteria because the cells rapidly undergo division and cell production will be easier to increase if needed in large quantities and the time needed for enzyme production will be shorter. Thermophilic microorganisms are known as bacteria that are tolerant of high temperatures, but on the other hand these bacteria are also able to survive at these temperatures. Where the purpose of research is to explain exploration of thermophilic bacteria. A review is conducted on the state-of-the-art methods using the preferred reporting items for reviews and meta-analyses (PRISMA) guideline. Bacteria have important economic value in human life. Knowledge in this branch of science is useful in medicine, hygiene, food science and nutrition, agriculture, and industry. Based on the results of macroscopic, microscopic and biochemical characterization, it was found that many bacteria with various types recording to their habitat or place of development, exploraton of thermophilic bacteria was carried out so that they could be useful for the industrial world.

Keywords: Bacteria; bacterial enzymes; industry; thermophilic bacteria

Introduction

Thermophilic bacteria have experienced very rapid development in the world of biotechnology with their properties, which are resistant to extreme temperatures. Its development is increasing with the increasing demand for enzyme production in biotechnology and industry. The progress of thermophilic bacteria in the world of biotechnology and industry has caused these bacteria to attract the attention of experts. So that indigenous microorganisms that are known to produce enzymes that play an important role in the industry will continue to be explored and researched in Indonesia (Sanka et al., 2023). Thermophilic microorganisms are known as bacteria that are tolerant of high temperatures, but on the other hand these bacteria are also able to survive at these temperatures.

Thermophilic bacteria are very suitable for use in the field of modern biotechnology and in the food and non-food industries (Ardhi et al., 2020). This bacterium is the only microorganism that has a very large opportunity to produce thermostable enzymes. Enzymes are biocatalysts that play an important role in cells that have different shapes and sizes. Thermostable enzymes are enzymes that are very effective at high temperatures and are not damaged by extreme temperatures. As the world of modern biotechnology develops, interest in these thermostable enzymes is increasing from year to year coming from the industrial sector (Che Hussian & Leong, 2023). The selection of enzymes derived from microbes has several advantages compared to those derived from animals and plants. One of the advantages is that the growth of enzymes will occur more quickly in bacteria because the cells rapidly undergo division and cell production will be easier to increase if needed in large quantities and the time needed for enzyme production will be shorter.

Bacteria comes from the Latin bacterium; plural: bacteria are a group of organisms that do not have a cell nucleus membrane. These organisms belong to the prokaryote domain and are very small (microscopic). This makes these organisms very difficult to detect, especially before the invention of the microscope. Bacteria generally reproduce or reproduce asexually (vegetative = not mating) by dividing. Cell division in bacteria is binary fission, in which each cell divides into two. During the division process, the genetic material also duplicates itself and divides into two, and distributes itself to the two new cells. Bacteria divide in a very short time. Under favorable conditions it duplicates every 20 minutes.

Bacteria are the most numerous and widespread organisms compared to other living things. Bacteria have hundreds of thousands of species that live in deserts, snow or ice, to the oceans. Organisms in order to grow need all the elements in their organic matter and all the ions needed for energy processing and catalysts. In additions there must be a source of energy to create the proton motive force and to allow the synthesis of macromolecules. The nutritional requirements and sources of metabolic energy for various microorganisms are very diverse (Biernat, 2016). Factors that affect bacterial growth are energy sources, which are needed for synthesis reactions that require energy in growth and restoration, maintenance of fluid balance, motion, etc., carbon sources, nitrogen sources, mostly for the synthesis of proteins and nucleic acids, a source of inorganic salts, especially folate and sulfate as anions; and potassium, sodium magnesium, calcium, iron, manganese as cations. Certain bacteria require additional growth factors, also called bacterial vitamins, in small amounts for essential metabolic synthesis.

Microorganisms are the most widely used source of enzymes compared to plants and animals. As a source of enzymes, microorganisms are more widely used in various industrial, agricultural, chemical, and medical products. Because it is more efficient, selective, predictable, reactions without side products, and environmentally friendly. These properties cause the use of enzymes to increase from year to year, the increase is estimated to reach 10-15% per year (Pazoki et al., 2021). Thermophilic bacteria have become an attractive source for thermostable industrial enzymes (Ginting et al., 2021). Thermostable enzymes exhibit a higher degree of resistance against eg denaturant proteins, detergents, extreme pH and organic solvents when compared to analogous mesophilic enzymes. Based on the background described above, it is necessary to study exploration of thermophilic bacteria.

Method

We conducted this research as a systematic review by following the PRISMA guidelines. The PRISMA guidelines provide several items that need to be considered in preparing a systematic review. In this study, we will mainly focus on several key items: Bacteria, Thermophilic bacteria, Bacterial enzymes, industry. This helps form the basis of our assessment. Initially, we collected the latest studies on the exploration of thermophilic bacteria, based on a few selected keywords. Then, we apply eligibility criteria to the collection. We only selected literature published in 2017 or later to provide an overview of recent trends. In addition, we limit the types of literature, namely only literature in the form of journals and proceedings.

Result and Discussion

Selected Reporting Items for Systematic Review (PRISMA) is the reporting technique used in this study. The research was carried out methodically during the necessary research phases. The information provided is comprehensive and impartial and aims to incorporate the results of relevant studies. The steps of a systematic literature review include developing research questions, searching the literature, screening and selecting relevant articles, screening and selecting the best research results, analyzing, synthesizing qualitative results, and preparing research reports. Writing the background and purpose of the study, collecting research questions, searching the literature, selecting articles, extracting articles, assessing the quality of the baseline study, and summarizing material are steps in the research process of a systematic literature review.

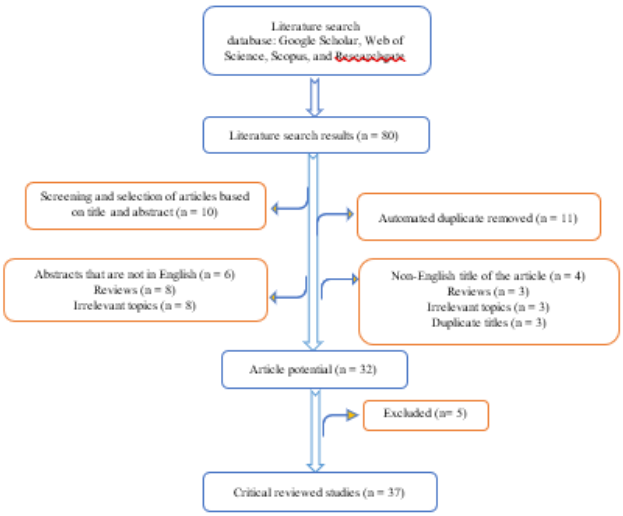

Figure 1. Flow process literatures search base on PRISMA guidelines

Table 1. Bacteria

Sources	Bacteria Shape
(Hofer, 2019); (Ramadhanti et al., 2021); (Constantino et al., 2016)	Coccus
(Djunaid et al., 2019)	Basil
(Farida Hikmawati et al., 2019); (Sampaio et al., 2022); (Huang et al., 2021)	Vibrio
(Du Toit, 2021); (Sayed et al., 2022); (Boyer et al., 2021)	Spiral

Complete articles published in international journals from 2016-2023, indexed in databases, and themed study exploration of thermophilic bacteria. Bacteria have a variety of shapes, but basically the structure consists of an imperfect nucleus with chromosomes consisting of closed loops of DNA. Several kinds of bacterial shapes, namely: Spherical; Bacteria that have a round or spherical shape are called cocci (coccus) which can be found in the genera Stapyhlococcus, Streptococcus, Neisseria, and others. Stem; Bacteria that have a rod shape are called bacillus bacteria and can be found in the Enterobactericeae family such as Escherichia coli (E. coli) and Klebsiella pneumoniae (K. pneumoniae). Like a comma; Bacteria that have a comma-like shape (bent rod) or vibrio can be found in the Vibrio cholera bacteria. Spiral; Spiral-shaped bacteria are found in the cause of syphilis, namely Treponema pallidum which has different arm lengths.

Table 2. Thermophilic Bacteria

Sources	The survival ability of this thermophilic microorganism is related to its cell structure which has several advantages
(Vavitsas et al., 2022); (Sohlenkamp & Geiger, 2016); (Wang et al., 2021)	Cell membrane structure
(Cebrián et al., 2017); (Parrilli et al., 2022);	Chaperonins
(Novik et al., 2019); (Villain et al., 2022); (Singh et al., 2021)	Structure of DNA gyrase

The ability of these thermophilic microorganisms to live is related to their cell structure which has the following advantages: The structure of the cell membrane is that the cell membrane of every living thing is composed of lipid and protein compounds called lipoproteins. Chaperonins are a type of protein that is very rarely found in other functional proteins in cells. This protein plays a role in maintaining the three-dimensional structure of cell functional proteins from denaturation of extreme environmental temperatures. The structure of DNA gyrase is a member of the topoisomerase enzyme group which plays a role in controlling the topology of a cell's DNA and plays an important role in the replication process in DNA transcription.

Table 3. Enzymes from thermophilic bacteria

Sources	Types of thermophilic bacterial enzymes
(Mantiri et al., 2019); (Soy et al., 2021); (Yassin et al., 2021)	Amylase Enzyme
(Solanki et al., 2021); (Finore et al., 2023)	Protease Enzyme
(Verma et al., 2021); (Ali et al., 2023); (Najm & Walsh, 2022)	Lipase Enzyme
(Yuzugullu Karakus, 2020);(Finore et al., 2023)	Catalase enzymes

Enzymes from thermophilic bacteria such as Amylase is a group of enzymes that have the ability to break glycoside bonds found in carbohydrate polymer compounds. Protease enzymes are one of the commercial enzymes that have high economic value and the utilization of enzymes has increased rapidly and occupies an important position in the field of technology and industry. The lipase enzyme is a fat breaker, glycerol ester hydrolase or triacylglycerol acylhydrolase and belongs to the class of enzymes that catalyze hydrolysis reactions. Lipase enzymes have activities that can hydrolyze various fats and oils in one unit of time. The catalase enzyme is a molecule formed from protein whose main function is as a catalyst. Catalyst is a process to speed up reactions in various chemical processes in the body.

Utilization of thermophilic bacterial enzymes in industries such as the processed milk industry; Milk contains a number of natural enzymes. There are 20 enzymes isolated from milk and identified as natural constituents. There are some that benefit the natural consumers of milk, some that affect the stability and shelf life of milk, and some that affect processed products from milk. Specific lipase especially increases the strength and stability of the dough. Gluten from wheat flour treated with lipase is stronger and more elastic. Therefore, lipase can be an alternative to chemicals for strengthening dough and emulsifiers.

meat processing industry; Meat that has been stored usually has undergone a protein breakdown process by the enzymes in the meat so that the meatballs produced are not chewy or softer. The bond between proteins in meat is the most dominant factor in determining the quality of processed meat products such as sausages and meatballs. Enzymes play an important role in the industrial world, such as the textile industry, detergents, food and beverages, chemicals, pharmaceuticals, and the leather industry.

Table 4. The role of thermophilic bacterial enzymes in the industrial world

Sources	Utilization of Thermophilic Bacterial Enzymes in Industry
(Okpara, 2022); (Zuliani et al., 2021); (Ozatay, 2020)	Processed milk industry
(Dahiya et al., 2020)	Bread industry
(Che Hussian & Leong, 2023); (Atalah et al., 2019); (Ejaz et al., 2021)	Meat processing industry
(Irdawati et al., 2020); (Mukherjee et al., 2023); (Mohammadi et al., 2022)	Pharmaceutical industry
(Emran et al., 2020); (Sikdar et al., 2023)	Detergent industry.

Conclusion

Bacteria have important economic value in human life. Knowledge in this branch of science is useful in medicine, hygiene, food science and nutrition, agriculture, and industry. Based on the results of macroscopic, microscopic and biochemical characterization, it was found that many bacteria with various types according to their habitat or place of development, exploration of thermophilic bacteria was carried out so that they could be useful for the industrial world.

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Author Contributions
Conceptualization, Yessy Aprihatin, Linda Andriani and Erpita Yanti ; methodology, Linda Andriani ; validation, Yessy Aprihatin and Erpita Yanti ; formal analysis, Erpita Yanti ; investigation, Yessy Aprihatin and Linda Andriani ; resources, Erpita Yanti and Linda Andriani ; data curation, Linda Andriani ; writing-original draft preparation, Erpita Yanti and Yessy Aprihatin ; writing-review and editing, Erpita Yanti ; visualization, Yessy Aprihatin and Erpita Yanti ; supervision, Linda Andriani ; project administration, Erpita Yanti ; funding acquisition, Yessy Aprihatin and Linda Andriani. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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