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Microalgae: laboratory growth techniques and the biotechnology of biomass production

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21.1 INTRODUCTION

Microalgae are photosynthetic micro-organisms which contain at least one type of chlorophyll – chlorophyll *a*. They are considered to be one of the most versatile groups of organisms in terms of their size, form and ecological function. Microalgae may vary in shape from small single cells of less than 1 μm in diameter to branched filamentous multicellular types. They are found in fresh-water habitats, marine environments and salt marshes, in hot springs and under ice.

Microalgae, including the prokaryotic types known as cyanobacteria (blue-green algae), play an important part in both aquatic and soil environments. For example, the nitrogen-fixing capability of cyanobacteria plays a crucial role in providing nitrogen fertiliser in rice fields and a number of other soils, and many green algae help to maintain soil structure. Furthermore, the role of algae in both water purification and pollution is

increasingly being recognised: there are opportunities to improve their participation in water treatment and in abating the problems of toxins produced in polluted water. In the aquatic food chain, primary production by microalgae leads to the growth and production of many fish and other seafood products. The importance of and demand for microalgae have therefore expanded with the growing industry of aquaculture.

The importance of algal culture in physiological and biochemical research, and the fact that algae are among the most efficient converters of solar energy to useful form, have led to increased interest in techniques of algal culture. Algal-culturing techniques can be divided into two categories: the first applies to laboratory conditions and a controlled environment, and the second to outdoor conditions for the large-scale production of biomass.

This chapter aims to provide basic techniques and concepts of algal culture and to present a state of the art report on algal biomass production, its problems and achievements. It is not the intention to provide a complete comprehensive manual of the techniques of algal cultivation, and the reader is encouraged to make use of the

*Photosynthesis and Production in a Changing Environment:
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references at the end of the chapter. However, I will try to present an overall approach to algal growth techniques and to point out problems which the scientist should be aware of when planning his or her own growth system and choosing the parameters to be measured.

In this chapter, I discuss only aquatic microalgae which grow photoautotrophically (i.e. requiring only light, CO₂ and inorganic nutrients) and reproduce solely by cell division.

21.2 GROWTH OF MICROALGAE: TECHNIQUES AND KINETICS

The algae dealt with here behave as simple microorganisms, undergoing a non-sexual life cycle and multiplying only by cell division. Hence common growth techniques and mathematical analyses used in bacteriological studies may also be applied to these algal cultures. Algae may be grown in batch cultures or in continuous culture.

21.2.1 Batch culture

A batch culture is initiated by the transfer of a small portion of a culture into a new culture medium, resulting in growth and an increase in biomass. Biomass concentration can be measured in many ways: as cell number, dry weight, packed cell volume, or in terms of any convenient biochemical component or parameter. The rate of increase in biomass concentration is generally expressed by the specific growth rate (μ), which is calculated according to the following formula:

$$\mu = \frac{1}{x} \cdot \frac{dx}{dt}$$

where x is the biomass concentration. Thus μ represents the increase in biomass per unit time per average biomass. Units are reciprocal time, i.e. s⁻¹ or d⁻¹.

The changes in specific growth rate during the development of a culture are shown in Fig. 21.1a. Fig. 21.1b shows the increase of

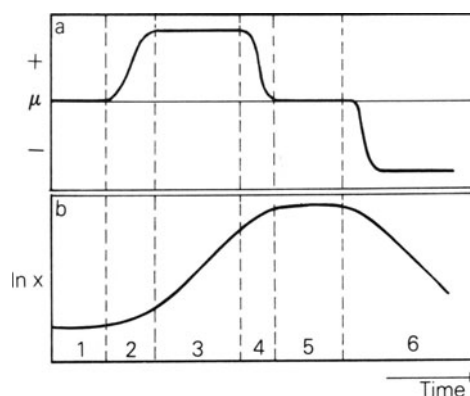


Fig. 21.1. Schematic representation of changes in (a) growth rate (μ) and (b) biomass (x) as a function of time in batch culture. Numbers refer to the various growth phases described in the text.

biomass concentration (x) with time (t) in such a batch culture. These figures indicate that the following phases can be distinguished in the growth of a batch culture: (1) lag phase, (2) accelerating phase, (3) logarithmic phase (balanced growth), (4) decelerating phase, (5) stationary phase, and (6) death phase. Each growth phase is a reflection of a particular metabolic state of the cell population at any given time. These phases of growth are considered in more detail below.

Lag phase:

A newly transferred culture may have a lag phase for several reasons.

- (a) The population transferred may have been in a metabolically 'bad' ('shifted down') state. This case occurs when the inoculum is taken from the stationary or death phase of the parent culture.
- (b) The freshly inoculated batch culture has first to become conditioned to the culture medium (e.g. through the chelation of metals by excretion products).
- (c) The measured biomass parameter does not take the non-viable portion of the population into account, and therefore, the biomass production of the small but vigorously growing portion of viable cells is masked by the non-viable cells