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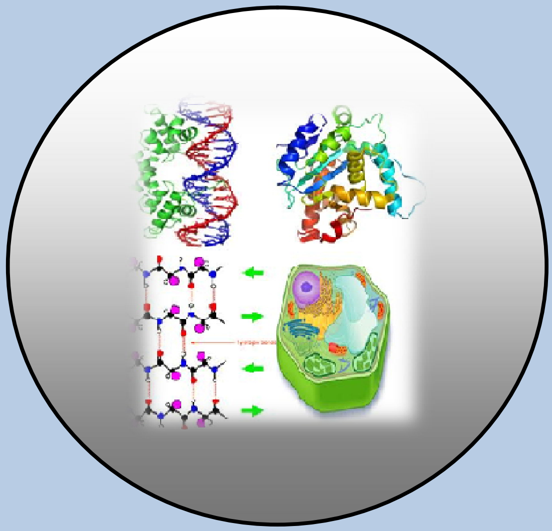

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REVIEW ARTICLE

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Physical, Biological and Chemical Regulatory Factors Influencing the Process of Biofermentation of Food: A Review

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ABSTRACT

Fermentation is a microbial technique and the reaction to be controlled in favorable and desirable conditions for food safety and quality after fermentation, especially in the production of alcoholic premium quality beverages like beer, wine and cider (Cavalieri et al., 2003; Steinkraus, 1995; Ganguly, 2012a; 2013). The same technology is employed in the bred manufacturing industries for leavening activity brought about by the production of carbon dioxide by the microbial or yeast activity. The preservation effect during fermentation is attributed to the production of lactic acid in sour foods such as yoghurt, dry sausages, pickles, sauerkraut and vinegar (extremely diluted acetic acid) [Steinkraus, 1995; Harden and Young, 1906].

Key words: Fermentation, Food processing, Physical Biological and Chemical Regulatory Factors.

INTRODUCTION

The term fermentation is derived from the Latin verb *fervere,* to boil, which describes the appearance of the action of yeast on extracts of fruit or malted grain during the production of alcoholic beverages. However, fermentation is interpreted differently by microbiologists and biochemists. Fermentation is a metabolic process converting sugar to acids, gases and/or alcohol.

It occurs in yeast and bacteria, but also in oxygen-starved human muscle cells. In its strictest sense, fermentation is the absence of the electron transport chain and takes a reduced carbon source, such as glucose, and makes products like lactic acid or acetate. No oxidative phosphorylation is used, only substrate level phosphorylation, which yields a much lower amount of ATP. Fermentation is also used much more broadly to refer to the bulk growth of microorganisms on a growth medium. The science of fermentation is known as zymology. The fermentation technology under controlled conditions is an age old practice both in households and industries for food processing and preservation, be it alcoholic beverage products of edible products derived from vegetable, fish and meat sources (Steinkraus, 1995; Ruddle and Ishige, 2010). Louis Pasteur, the renowned French chemist is the world famous and first known zymologist in history, who in 1856 established the pivotal role of yeasts in fermentation. Pasteur originally defined fermentation as “respiration without air” after regular performances of lengthy experimental protocols (Dubos, 1995). After observation of the breakdown of sugars to alcohols by the action of yeast, the pioneer concluded that the entire reaction is driven by the chemical catalytic action of certain forces called ferments inside the yeast cells. It was further observed that the yeast extracts can bring bout fermentation of sugars even also in the absence of viable yeast cells. In 1897, Eduard Buchner of Humboldt University of Berlin, Germany discovered that sugars are fermented in the absence of viable cells also in the fermentation mixture. The yeast cells secrete a chemical component called zymase. For his memorable contributions in research and discovery of cell-free fermentation, in 1907 Buchner was awarded with the prestigious Nobel Prize in Chemistry. In 1906, NAD^+ was discovered out of studies carried out from ethanol fermentation (Lin *et al*., 2012). Fermentation is brought about by the conversion of sugars into ethanol chemically (Ganguly, 2012a). The fermentation technology applicable to food processing sector is also popularly known as zymology or zymurgy. Fermentation is an important and popular technique in food processing technology. It is resulted from the chemical reaction resulting from the breakdown of higher carbohydrates to alcohols and organic acids or alcoholic derivatives. Microorganisms are capable of growing on a wide range of substrates and can produce a remarkable spectrum of products. The relatively recent advent of *in vitro* genetic manipulation has extended the range of products that may be produced by microorganisms and has provided new methods for increasing the yields of existing ones. The commercial exploitation of the biochemical diversity of microorganisms has resulted in the development of the fermentation industry and the techniques of genetic manipulation have given this well-established industry the opportunity to develop new processes and to improve existing ones. The chemical equation below shows the alcoholic fermentation of glucose, whose chemical formula is $C_6H_{12}O_6$. One glucose molecule is converted into two ethanol molecules and two carbon dioxide molecules:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

Before fermentation takes place, one glucose molecule is broken down into two pyruvate molecules. This is known as glycolysis.

BIOFERMENTATION

Fermentation technology is primarily employed for the preservation of different food by production of acids and alcohols, biological fortification and enrichment of food items with potential biogenic products like essential amino acids, easily digestible proteins, essential fatty acids and useful vitamins, neutralization of anti-nutritional factors, to diversify and enrich the diet with various aromas, flavors and textures in food substrates and decrease in requirements of further processing techniques like cooking etc (Steinkraus, 1995). Bio-fermentation technology makes it possible to grow a number of fungi in large tanks and in a matter of days large quantity can be produced. The technology has now become highly advanced and is making previously rare herbs like Cordyceps and Ganoderma much more accessible. Many studies indicate that the chemical nature of this biotechnology Cordyceps is almost identical to that of the wild variety. The Cordyceps contained in most commercial products is produced by this technology (Macfarlane and Macfarlane, 1993).

ADVANTAGES OF BIOFERMENTATION

Standardization

Highly controlled by scientific means during its growth and "standardized", every batch is virtually identical and, in a sense, "perfect." This is very important in pharmaceutical terms because without standardization, it is difficult or impossible to develop drug-type standards for substances like Cordyceps. Once an herb can be standardized, all kinds of studies can be conducted that will be accepted by the scientific community. However, standardization, by itself, does not make a product effective.

Cost

Products can be produced more cheaply by bio-fermentation. High quality wild Cordyceps is rare. The culture-grown Cordyceps is available at a third of the cost, with approximately the same benefits. Fermentation technology makes this substance more readily available.

Vegetarian

Wild Cordyceps, by weight, is mostly caterpillar. For vegetarians, and those who do not want to consume caterpillars, the new technology provides a solution. The fermentation technology does not include the caterpillar in the growing process. The fungus is grown without the use of animal nutrients and the result is a 100% pure "vegetarian" health product (Macfarlane and Macfarlane, 1993).

FACTORS REGULATING FERMENTATION

Physical factors

Temperature

Temperature has an impact on the growth and activity of different strains of yeast. At temperatures of 10 to 15°C, the non-Saccharomyces species have an increased tolerance to alcohol and therefore have the potential to contribute to the fermentation when the temperature increased, the maximum fermentation time gets shortened, but a much higher temperature inhibited the growth of cells and then the fermentation significantly declined (Lin *et al*., 2012). This phenomenon may be explained because the higher temperature results in changing the transport activity or saturation level of soluble compounds and solvents in the cells, which might increase the accumulation of toxins including ethanol inside cells (Lin *et al*. 2012). Moreover, the indirect effect of high temperature might also be ascribed to the denaturation of ribosomes and enzymes and problems with the fluidity of membranes. However, at lower temperatures the cells showed lower specific growth rates which may be attributed to their low tolerance to ethanol at lower temperatures. It is commonly believed that 20 to 35˚C is the ideal range for fermentation and at higher temperatures almost all fermentation would be problematic (Macfarlane and Macfarlane, 1993).

Influence of substrate concentration

The production of ethanol is affected by the substrate concentration higher substrate concentration may achieve higher ethanol production, but a longer incubation time was required for higher initial glucose concentrations. Moreover, higher initial glucose concentrations may have actually decreased the ethanol conversion efficiency when the pH value is not controlled, since the higher substrate and production concentrations may have inhibited the process of ethanol fermentation. More substrate did not improve the specific ethanol production rate when the pH value is not controlled.

Influence of pH

Improved ethanol fermentation activity can be achieved by controlling various parameters. In addition to temperature and substrate concentration, pH is also a key factor that affects ethanol fermentation. When the pH is lower than 4.0, the incubation time for maximum ethanol concentration became prolonged, but the maximum concentration is not very low. When the pH value is above 5.0, the quantity of ethanol produced substantially decreased. Therefore, a pH range of 4.0 to 5.0 may be regarded as the operational limit for the anaerobic ethanol production process (Lin *et al*., 2012).

Chemical factors

Several studies have been carried out to study the biochemical pathways followed during the degradation process of fish fermentation (Ruddle and Ishige, 2010). Strong odour in spoilt fish may be a reaction between TMAD and lactic acid producing TMA and acetic acid. The following are the chemical changes in deteriorating fish (Macfarlane and Macfarlane, 1993):

i. Enzymic degradation of nucleotides and nucleosides in the flesh leading to the formation of inosine, hypoxanthine, ribose, etc.
ii. Bacterial reduction of trimethylamine oxide (TMAO), a non-volatile and non-odoriferous compound, to volatile trimethylamine (TMA) which has an amoniacal smell.
iii. Formation of dimethylamine (DMA).
iv. Breakdown of protein with subsequent formation of ammonia (NH_3) indole, hydrogen sulfide, etc.
v. Oxidative rancidity of the fat.

Volatile bases particularly TMA, DMA and NH, are associated with changes in the organoleptic and textural quality of fish (Ruddle and Ishige, 2010). The development of a specific aroma in fermented fish sauces and pastes may not be due to the action of micro-organisms. In a recent study it was found that micro-organisms play little or no part in aroma production. It can therefore be concluded that the microbiology of any salted, dried or fermented fishery product is greatly influenced by the natural micro-flora of the fish, the salt and the conditions under which processing takes place (Ruddle and Ishige, 2010).

SUMMARY

There are certain risks and health hazards associated with excess and regular consumption of fermented food products. In Alaska, since 1985, there has been increase in incidences of botulism exceeding the case reported in the Americas. This is mainly caused for the practice of allowing whole fish, fish heads and meat of animals like sea lions, walrus, whale flippers, birds, seal tallow, beaver tails etc. to ferment for prolonged periods before consumption by the resident Eskimos there. During this extended fermentation, if plastic wrappers or containers are used, then *Clostridium botulinum* gets a conducive condition to thrive in the microaerophilic condition inside the plastic containers (Ganguly, 2012b; 2013).

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