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Review

Biotechnological use of *Candida* yeasts in the food industry: A review

Marek KIELISZEK*, **Anna M. KOT**, **Anna BZDUCHA-WRÓBEL**, **Stanisław BŁAŻEJAK**, **Iwona GIENTKA**, **Agnieszka KURCZ**

Faculty of Food Sciences, Department of Biotechnology, Microbiology and Food Evaluation, Warsaw University of Life Sciences – SGGW, Nowoursynowska 159C, 02-776 Warsaw, Poland

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ABSTRACT

Yeasts of the *Candida* genus comprise a group of microbes with a significant potential for industrial use. This work presents some directions for biotechnological use of these microbes. The first includes utilization of biomass of *Candida utilis* yeasts as a source of microbial proteins, rich in exogenous amino acids, including lysine. Biomass of *Candida* yeasts is also a source of β-glucans, glucomannan, and mannoproteins with anti-genotoxic, anti-neoplastic, and antioxidative properties. *Candida* yeast cells may collect and accumulate elements from their cultivation medium, often in amounts exceeding their natural demand, forming bioplexes, for example, with selenium or magnesium. Thanks to these properties, biomasses of these yeasts may provide a fully valuable additive to feedstocks. The second direction of biotechnological use of *Candida* yeasts is related to the production of extracellular metabolites such as citric acid, ethanol, xylitol, erythritol, biosurfactants, and exopolysaccharides. These substances are used in the food processing industry, the pharmaceutical industry, and the cosmetic industry.

1. Introduction

Intensive development of biotechnology has resulted in continuously increasing numbers of technological processes performed using microorganisms. Such processes provide an alternative for the chemical industry, the operations of which pose hazards to the environment. Yeasts are a group of microbes with a vast practical potential in biotechnology. These microorganisms do not have particularly high nutritional requirements, exhibit high rates of growth and their cultivation does not depend on geographic and environmental conditions (Santos *et al.*, 2013). Yeasts are more easily accepted than other microorganisms by the society because of their usefulness, for example, in the production of wine and beer. The prospects of biotechnological application of *Candida* yeasts have been presented to provide a better picture of the significance of these unconventional types of yeasts. The potential of these microbes as a source of microbial proteins, polysaccharides, and bioplexes in human and animal nutrition was indicated. In addition, the possibilities of biosynthesis of other metabolites such as xylitol, erythritol, citric acid, ethanol, and biocatalysts such as lipases were presented. The role of

* *Corresponding author*. Fax: +48 225937681.
E-mail addresses: marek-kieliszek@wp.pl, marek_kieliszek@sggw.pl (M. Kieliszek).
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Candida yeasts in the production of selected, fermented drinks was also considered.

2. Characteristics of *Candida* yeasts

The genus of yeasts known as *Candida* was separated in 1923 by Danish microbiologist, Christine Berkhout, who assigned nine species previously included in the *Monilia* genus to the new taxonomical unit (Barnett, 2004). The genus name of these microorganisms originates from the Latin word *candidus* (white), related to the absence of carotenoid dyes in cells of these fungi (Barnett *et al.*, 2000). The *Candida* genus was separated back then based on determination of selected morphological, biochemical, and physiological characteristics. During the last few decades, the development of advanced molecular biology methods resulted in significant changes to the nomenclature of *Candida*. Currently, the genus includes approximately 200 species (Brandt and Lockhart, 2012), which are members of the fungal kingdom, Saccharomycetaceae family, Saccharomycetales order, Hemiascomycetes class, Ascomycota (Fungi) phylum (Barnett *et al.*, 2000).

Candida genus yeasts are unicellular. The shape and size of the cells depend mainly on the species, the growth phase, the physiological condition, and on the environmental conditions of the culture (Fig. 1). They are usually oval, ellipsoidal, or strongly elongated, and their size is in the range of (1–8) × (1–6.0) μm (Kurtzman and Fell, 1998; Singleton and Sainsbury, 1987). *Candida* genus yeasts are typically aerobic microbes. During aeration, they produce small amounts of alcohol or do not produce it at all, at the same time quickly increasing their biomass (Barnett *et al.*, 2000). Optimal temperature and pH are, respectively, 25–30 °C and 4.0–6.0 (Kurtzman and Fell, 1998). The discussed microbes reproduce asexually—vegetatively, by budding. The *Candida lipolytica* variety is an exception, wherein a sexual cycle was observed in its case in 1972 (Yarrow, 1972). Yeasts of this genus may form residual mycelium, well-developed mycelium, or do not form it at all. This depends mainly on their species and on environmental conditions. They do not synthesize carotenoid dyes and do not assimilate nitrates and inositol (Singleton and Sainsbury, 1987). Because of the species variety in the *Candida* genus, determination of the ability to ferment or to assimilate saccharides for the genus as a whole is virtually impossible.

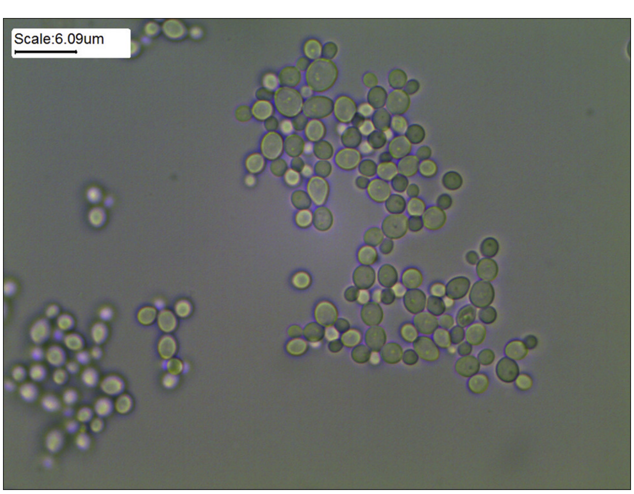

Fig. 1 – Microscopic image of *Candida utilis*.

3. Production of microbial proteins as the traditional direction of practical use of *Candida* yeasts

The increased rate of the global protein deficit has led to the search for new, alternative methods of protein production. Single-cell protein production (SCP) is one of the solutions to this problem. A range of advantages of microbial proteins was shown (Kurcz *et al.* 2016a; Rywińska *et al.*, 2013), which make it better than plant-derived and animal-derived proteins. The most important benefits of SCP use include: short time of microorganism generation, high protein content in the cells and the ability to shape the amino acid profile of proteins by regulating the substrate composition, cultivation conditions, or through genetic modifications. At the same time, SCP production may be performed as a continuous process and does not depend on climatic conditions (Kurcz *et al.*, 2016b). In the past several years, the possibility of using unconventional raw materials in the production of yeast biomass has attracted increasing attention. Such raw materials include, for example, fat production waste, meat production waste, orange pressings, milled waste from shrimp shells, or the glycerin fraction obtained during biodiesel fuel production. These raw materials provide an assimilable carbon source for species such as *C. tropicalis*, *C. utilis*, or *C. lipolytica* (Kurcz *et al.*, 2016a; Nigam, 2000; Rywińska *et al.*, 2013; Yadav *et al.*, 2014). Industrial waste management in yeast cultivation allows the costs of biomass production to be reduced, together with disposal of industrial waste that is difficult to store (Kurcz *et al.*, 2016a,b).

Nigam (2000) studied the possibility of using hydrolyzate from sugar cane pressings as a carbon source in SCP production by yeasts *Candida langeronii* RLJ Y-019. The biomass obtained after cultivation was characterized by the high content of intracellular protein (48.2 %), and lysine had the highest share of all present amino acids (7.8 %). The content of lysine was higher than that in soy beans (6.6 %), wheat (1.9 %), or feedstock for ruminants (3.3 %). Lysine content in SCP may be increased using mixed cultivation of yeasts with lactic fermentation bacteria. Rajoka *et al.* (2012) found the content of lysine after the cultivation of *C. utilis* and *Brevibacterium lactofermentum* bacteria reaching up to 25 %, whereas the content of protein proper in the biomass was 32 %. Thanks to the high content of lysine, a limiting amino acid in plant-derived feedstocks, the obtained biomass of yeasts may be used as a feedstock additive. Adequate amino acid composition is required in order to ensure proper growth and development, in particular in young animals (Kurcz *et al.*, 2016b). *Candida utilis* yeasts are commonly used in the production of various preparations, examples of which include protein hydrolyzates or yeast extracts. The interest in cellular proteins of feedstock yeasts is a result of their balanced amino acid composition. Extracts, autolyzates, or yeast hydrolyzates used as food additives may intensify the flavor or the smell of food. Because of