Recycling of yeast multifunctional autolysates and extracts in the food industry

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Abstract. Recycling of industrial waste is one of the most crucial problems for the food industry. The forces of modern researchers are focused on solving this problem and using the biopotential of spent resources. Residual yeast from fermentation industries, in particular brewing, is of particular interest among the variety of food production waste. This is due to the extremely rich chemical composition of the yeast cell, and the possibility of obtaining a wide range of ingredients that exhibit both biological activity and technologically significant properties. Spent brewer's yeast is rich in proteins and carbohydrates, as well as vitamins B and minerals. The protein fraction, which accounts for 45–60% by dry weight (dw), contains all essential amino acids in sufficient quantities, which allows considering this secondary material resource an excellent source of protein with high biological value and a well-balanced AA profile. The carbohydrate fraction, comprising approximately 40% by dw, consists of intracellular carbohydrates (such as simple sugars and glycogen) as well as cell wall polysaccharides (such as β-glucan and α-mannan). Special emphasis is placed on the cell wall components due to their significant multidirectional biological activity and technologically important properties. Thus, β-glucan and α-mannan, along with emulsifying, sorbing and stabilizing properties, exhibit antioxidant and antimicrobial activity, immunomodulatory and prebiotic properties. This review presents an analysis of yeast autolysates and extracts sources as well as the influence of cultivation conditions and production methods on their chemical composition.

1 Introduction

Annually worldwide production of the brewing industry is about 0.4 billion tons of spent beer yeast (SBY) and more than one billion tons of beer pellets and hops [1]. Despite the high potential of the closed-loop economy in various sectors such as food, feed, pharmaceuticals, and cosmetics purpose, SBY is used as a raw material for animal feed. SBY has a valuable composition, it contains high-quality proteins (45–60% by dw), carbohydrates (15–35% by dw), nucleic acids (4–8% by dry weight (dw)), lipids (4–7% by dw), a complex of B group

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vitamins, minerals, and dietary fibers [2]. In addition, SBY is an excellent source of biologically active peptides, which allows using them to produce biologically active compounds (BACs) and functional foods.

In fact, the development of new strategies for recycling by-products of brewing industries is of environmental and economic importance. Innovative and inexpensive protein sources with high biological activity and functional properties are being actively studied all over the world. SBY is the second most important by-product of the brewing industry, and despite their nutritional (about 50% protein by dw) and technological potential, they are still underused or needs recycling [3]. The yeast cell wall (YCW) of SBY has be destroyed to release intracellular proteins and cell wall proteins. There are various methods of destruction of YCW, such as induced autolysis, enzymatic hydrolysis, destruction of cells by ultrasound, and mechanical treatment with glass beads.

2 Sources of BACs

2.1 *Saccharomyces cerevisiae*

Saccharomyces cerevisiae (S. cerevisiae) is widely employed in the food, feed, and pharmaceutical industries due to its rich protein and amino acid (AA) content. Its use as a source of nitrogen in the form of food yeast biomass or extract makes it an economically appealing option for scientific research geared towards industrial applications [4].

In addition to specially grown biomass, SBY *S. cerevisiae* are also used. This source of biologically valuable autolysates is the most promising in the future, as it allows using the residual resource of fermentation industry [5].

Comparative analysis of *Kluyveromyces marxianus* (*K. marxianus*) and *S. cerevisiae CBS 1907* demonstrated no differences. Approximately 2.2–3% by dw carbohydrates, 9.5–12% by dw proteins, 0.6–1.0% by dw DNA, and 6–7% by dw RNA was isolated in autolysates [6]. *K. marxianus* biomass can become a source of yeast autolysates employed within the food industry addition to the classic SBY of *S. cerevisiae*.

In comparison to the chemical, functional and taste properties of yeast dry extract obtained from *S. cerevisiae TGM10*, *S. boulardii S11* and *K. marxianus TGM66*, the most protein-rich sample was *S. cerevisiae TGM10* extract (69.17% by dw), followed by extracts of *S. boulardii S11* (66.16% by dw) and *K. marxianus TGM66* (62.42% by dw), respectively. *S. cerevisiae TGM10* extract was also the richest yeast extract of essential AA [7]. These strains demonstrate the potential to produce yeast extracts to increase the nutritional value of food products.

2.2 Non-*S. cerevisiae yeast*

Candida spp.

Candida species are characterized by their ability to utilize various substrates and exhibit a short generation time. The biomass of Candida spp. is rich in protein, vitamins, and minerals, and contains a small percentage of nucleic acids [8]. Additionally, certain yeasts within the Candida genus have the capacity to absorb phenolic compounds. Candida biomass, cultivated on agro-industrial waste, is particularly rich in phenolic compounds and may possess antibacterial, antifungal, antiviral, and antioxidant properties [9].

Yarrowia lipolytica

Yarrowia lipolytica, a non-pathogenic and exclusively aerobic yeast, is renowned for its ability to produce numerous metabolites crucial for the cultivation of both hydrophilic and

hydrophobic non-traditional substrates. These substrates include fats derived from vegetable or animal waste, waste generated during the production of oil and biofuels, among others [10,11]. Furthermore, the protein biomass of Y. lipolytica serves as a valuable source of B-group vitamins, including vitamin B12 [12].

3 Obtaining yeast hydrolysates

The process of obtaining yeast autolysates is extremely diverse. Cell destruction is achieved in various ways, such as autolysis, mechanical grinding with glass beads, enzymatic hydrolysis, and ultrasonic treatment. Each of the methods can influence the quantitative content of free AA, peptides, and other important components. Moreover, the strain affiliation of the culture and the method of yeast cultivation or SBY regeneration should be considered. Figure 1 reveals a scheme for obtaining products from yeast biomass.

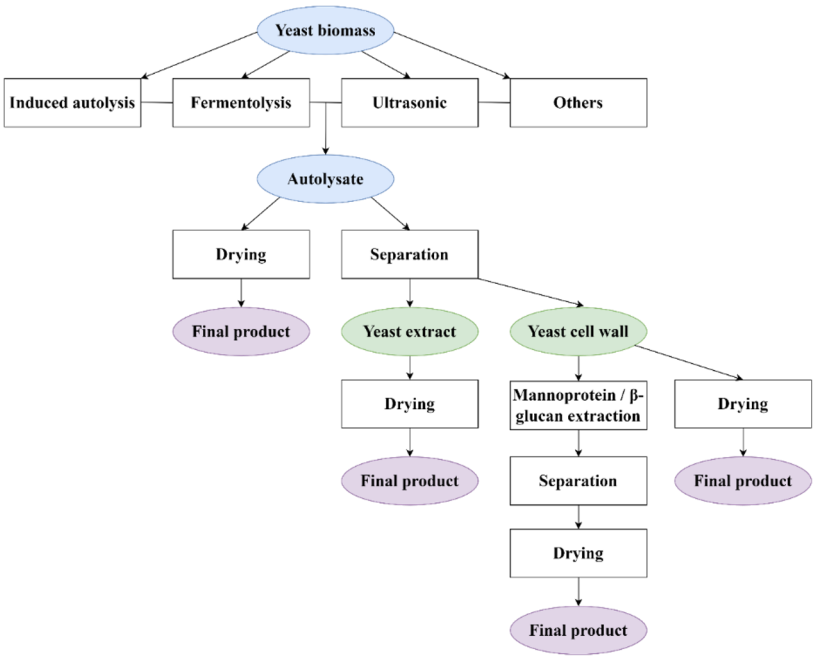

Fig. 1. Options for obtaining finished products.

3.1 Enzymatic hydrolysis

The choice of culture growth conditions has a significant impact on intracellular or free AA profiles. When *S. cerevisiae* was cultured under aerobic and anaerobic conditions, it was shown that intracellular concentrations of glutamic acid (Glu) were 18 times higher in aerobic yeast [13]. Glu passes into autolysates and hydrolysates. Given the high flavor activity of this acid (umami), autolysates and yeast extracts can be used as natural flavor enhancers, and the growing method directly affects the organoleptic profile.

Proteolytic enzymes are usually used for enzymatic hydrolysis and are more effective in releasing AA than autolysis. However, the improved enzyme performance is most significant when applied to aerobic yeast. The choice of yeast growth conditions and hydrolysis enzyme can be used to change the profile of free AA and the yield of hydrolysates. Papain and alkaline

protease of aerobic yeast allows obtaining hydrolysates with high levels of umami, bitter and essential AA. Bromelain autolysates and hydrolysates from aerobic yeast have low levels of bitter and essential AA with high Glu content.

The protein hydrolysate obtained with neutrase increased the number of DPPH radicals (116,9 ± 2,9 μM Trolox equivalents TE/g dw), followed by hydrolyzation1with trypsin (102,8 ± 2,7 μM TE/g dw). During ultrafiltration, the fraction of low molecular weight peptides (<3 kDa) released by bromelain showed the highest antioxidant activity (AOA) (50,06 ± 0,39 μM TE/g dw) [1].

Enzymes affect the foaming properties and emulsifying ability of hydrolysates. Trypsin provides protein hydrolysate with the highest foaming and stability [13]. These results indicate that the studied proteases are suitable for modulating the overall functionality of yeast proteins.

3.2 Autolysis

The classical method of obtaining various yeast hydrolysates is induced autolysis followed by enzyme inactivation.

During the autolysis of *S. cerevisiae*, an increase in the content of free AA was corelated with an increase in the process time, which reached the levels of 11.2% and 77.5% after two and 48 hours, respectively [14]. In addition, the profile in this case depends on the composition of the wort.

3.3 Ultrasonic treatment

Ultrasonic treatment of yeast biomass leads to the significant increase in the extraction of lipids from yeast cells [15]. *S. cerevisiae* is extracted using ultrasonic treatment (power: 400-1000 W; frequency: 20 kHz; operating time: 2-8 h; temperature: 70°C) [16].

3.4 Other types of hydrolysate production

We have confirmed the selective release of intracellular compounds from *S. cerevisiae* treated with a pulsed electric field. Electrical treatments, such as high-voltage electrical discharge and pulsed electric field, consistently result in incomplete damage to yeast cells, leading to varying extraction efficiencies of ionic substances, proteins, and nucleic acids. Additionally, employing separate ultrasound procedures enables the extraction of protein with reduced levels of ionic components and nucleic acids [17]. Electric pulse treatment seems to provide advantages for the subsequent purification process [18]. Therefore, to obtain inactivated yeast autolysates, electrical treatments should be combined with other methods that destroy the cell.

4 Drying

Yeast autolysate can be concentrated using such well-known methods as reverse osmosis, ultrafiltration, or evaporation [19]. Preferably, the yeast autolysate is concentrated by evaporation. After concentration, it can be dried and transformed into a ready-made form.

Likewise, yeast autolysate is concentrated by evaporation and spray drying. The selection of the method depends on the desired concentration of the autolysate. The ready-made autolysates are produced in the form of concentrates from 80%, fine powder, flakes, and dry pressed pellets.

5 Application

5.1 Animal feed and aquaculture nutrition

At present, the primary market for beer yeast autolysates is within the feed industry, primarily serving as an economical source of protein, minerals, and B-group vitamins. Beer yeast autolysates can be incorporated into feed either as a wet suspension or after drying [20]. The addition of yeast to animal feed has a positive effect on feed quality.

This source of protein (SCP) has been proven to be a good substitute for other expensive protein sources such as fish and soy meal. Thus, it can be concluded that SCP can easily replace traditional (plant and animal) protein sources in the diets of humans, animals, and fish without any harmful effect [21,22]. Typically, in aquaculture, yeast extracts are implemented to increase the digestibility of food [23,24].

5.2 Material Production

Yeast cells, particularly due to their protective cell wall properties, are considered an ideal material for encapsulating biologically active compounds [25].

The protein autolysate derived from *S. cerevisiae* is utilized as a carrier material for microencapsulation of oil, providing protection against oxidation [26]. Heat treatment of SBY induces the Maillard reaction, resulting in both darkening and improved functional properties of the proteins, such as increased solubility. Subsequent to the Maillard reaction, BY hydrolysates can be employed for encapsulating ascorbic acid via spray drying, ensuring stability and facilitating broad application within the food industry [20].

5.3 Antioxidant properties

Yeast hydrolysates have the potential to be used as food or nutraceutical ingredients due to their antioxidant properties [20,27]. The most effective method of obtaining yeast autolysate in the study of AOA is enzymatic hydrolysis. During fermentation, the internal cellular components, including nutrients and enzymes, are extracted by 63% more efficiently [28].

5.4 Flavor components

Yeast autolysates are used as food additives or flavorings. They are frequently utilized to enhance savory flavors and impart umami taste sensations, and can be found in a wide range of packaged foods, including frozen meals, crackers, snacks, sauces, broths, and other products. These hydrolysates hold particular significance for vegans and vegetarians. As mentioned above, yeast extract and fermented foods contain Glu, which gives the food a taste of umami [29].

5.5 Bioactive peptides

Bioactive peptides have gained popularity across various economic sectors for their demonstrated biological benefits for the human digestive and immune systems. The extraction of these peptides from fermented byproducts to produce functional ingredients represents a crucial step in meeting the increasing demand and promoting closed-loop economy industries [30]. Protein-rich extracts and autolysates derived from *S. cerevisiae* are rich sources of bioactive peptides.

5 Conclusion

In summary, the functional properties of the autolysates and extracts obtained are influenced by yeast suspensions rich in AA and BACs, which result from the interaction of yeast with wort and hops during the beer production process.

Yeast autolysates obtained through various methods, as well as extracts, are characterized by high amino acid content, antioxidant and functional properties, and diverse sensory profiles.

The use of yeast hydrolysates can significantly change and improve the environmental and economic values through the processing of by-products in fermentation industries.

The range of yeast autolysates application is growing every year in such spheres as food production, agriculture, cosmetology, and even medicine.

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