Applied Biological Research 21(2): 105-113; (2019) **REVIEW ARTICLE**
DOI: 10.5958/0974-4517.2019.00020.X

BAKER'S YEAST: INDUSTRIAL APPLICATIONS AND HEALTH BENEFITS

Jaspreet Kaur and Priya Katyal*

Department of Microbiology, Punjab Agricultural University, Ludhiana - 141004, Punjab (India)
*e-mail: *drpkatyal@pau.edu*

(Received 3 January, 2019; accepted 12 June, 2019)

ABSTRACT

Baker's yeast is used as a leavening agent in bread baking as it converts simple fermentable sugars in dough to CO_2 and ethanol. Fermentation by yeast leads to the expansion of dough, its maturation and development of characteristic flavours in cereal-based products. Different strains of yeasts like *Saccharomyces cerevisiae, S. exiguous, S. boulardii,* etc. are widely used in nourishment and pharmaceutical industry. Yeast is a source of vitamin B, minerals, β-glucan fiber and protein and is used as health supplement. As probiotic, it plays a vital role in folate biofortification, detoxification and bioavailability of nutrients. Anti-cholesterolemic, anti-mutagenic, anti-oxidative and anti-tumuor potential of *S. cerevisiae* is currently under investigation. Yeast is exploited in several industrial processes including bioethanol production and bioremediation and is an excellent tool for biotechnological applications. This paper reviews the work done on baker's yeast and its industrial application and health benefits.

Key words: Anticancer, bioremediation, health supplement, probiotic, yeast

1. INTRODUCTION

Yeasts constitute a substantial heterogeneous group of microbes that currently draws considerable attention from researchers and industry (Hatoum *et al.,* 2012). The term "yeast" is derived from Dutch word "*gist*" which means 'to form foam during maturation of beer wort'. The other words referring to yeast include French word "*levure*" which refers to the part of yeast that induces bread mixture to rise. Oberwinker classified yeasts as unicellular chemoorganotrophic fungi belonging to ascomycetes or basidiomycetes [~ 75 µm in dia.] that reproduce by budding or fission (Van der Walt, 1970). Yeast has served mankind since golden age. For many centuries the baker's yeast products are used as important part of well-balanced diets. By the end of 19th century, the addition of exogenous yeast biomass became a common practice to produce bread and beer. Proximate analysis of fresh baker's yeast has revealed 30-35% dry material, 7.0-9.3% nitrogen, 41-58% proteins, 35-45% carbohydrates, 4-6% lipids and 5-7% minerals and vitamins; whereas dried baker's yeast constitutes 34% proteins, 36% carbohydrates, 1.5% fats, 8.1% minerals and vitamins/enzymes (Bekatorou *et al.,* 2006). Yeasts contain good level better-quality proteins. Yeasts are most versatile organisms having considerable significance in food, medicine, agriculture and scientific area. This paper reviews the work done on baker's yeast and its industrial application and health benefits.

2. BAKER'S YEAST IN FERMENTATION

Common industrial property of yeasts is their vital role in fermentation like beer, wine, distilled spirits (whiskey, tequila, rum and brandy), bakery products (food additive, conditioner & flavouring agent), sausages and cheese manufacture. Yeast is also involved in the production of ethanol, single cell protein, industrial enzymes and many other metabolites (Basso *et al.,* 2008). Baker's yeast (*Saccharomyces cerevisiae*) is currently used as a model organism for comparative studies in eukaryotic biology and are progressively being utilized as hosts for the expression of protein

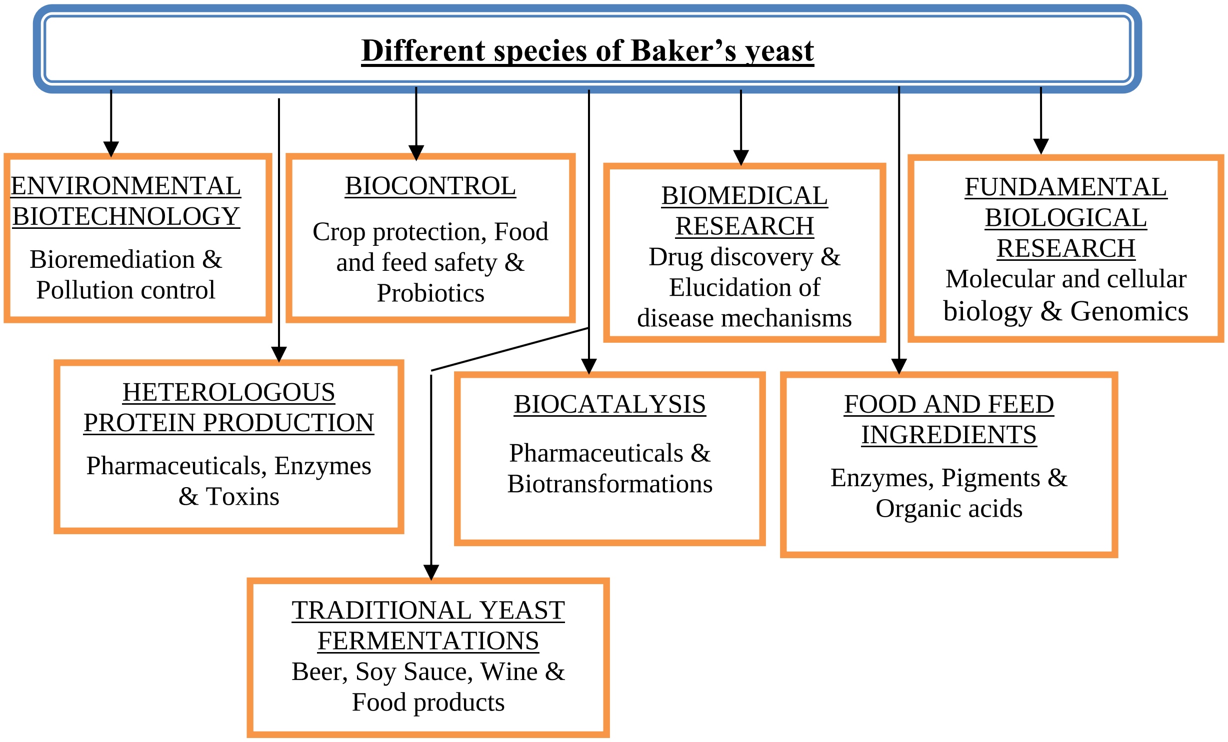

Fig. 1: Exploitation of Baker's yeast (*S. cerevisiae*) in different biotechnological industries

biocatalysts and multi-catalyst pathways for the synthesis of chemicals and little sub-atomic weight compounds of nutritional and medicinal importance (Johnson and Echavarri-Erasun, 2011). Yeast has crucial role in bioremediation and as biocontrol agent in agriculture. Yeast is a good indicator of environmental quality. Many of these processes have reached communal utility, while others are under development.

Baker's yeast has several industrial applications (Fig. 1; Table 1). With increase in industrialization, the manufacture and demand of fermented products has grown exponentially (Gómez-Pastor *et al*., 2011). To ensure fast and complete fermentation, the modern food industries require huge quantities of effective yeasts to make high quality products (Gómez-Pastor *et al.*, 2011). These industries prepare different product-formulations under various commercial brand names.

3. BAKER'S YEAST IN BIOETHANOL PRODUCTION

The excessive use of fossil fuels has led to the global warming (Hoekman, 2009; Perera, 2017). To reduce greenhouse gas emission, the fossil fuels need to be replaced by bioresource fuel and renewable clean energy. Global petroleum production and prices have shown steep rise and the energy crisis issue has impacted world politics and human life (Gómez-Pastor *et al*., 2011). Therefore, there is need for sustainable energy source as an alternative feed stock. The form of sustainable energy sources from the middle of 21st century have been delivered from regular farming feedstock like molasses, potato, sugar-cane, maize, etc. (Al-Farsi *et al.*, 2007).

Biofuels including bioethanol and biodiesel (which are biodegradable and less toxic than fossil fuels) depend on the transformation of sustainable feedstocks to fuels, with current focus principally on the assimilation of biomass and lignocellulose sources like plant leftovers, perennial grasses and other materials (Richard, 2006). Because of oil crisis in 1973 and 1979, Brazil produced industrial bioethanol innovation based on yeast aging of sugars (Goldemberg, 2007; Wu *et al.*, 2009). As of now, roughly 55% of collected sugarcane in Brazil is utilized for ethanol production, and biomass fulfills around 30% of the nation's vitality requirements. Ethanol plants in Brazil generally use baker's yeast, as a result of its minimal cost, easy accessibility in desired quantity,

Table 1: Baker's yeast formulations and manufacturing industries in India

Classification		Properties	Uses	Manufacturing industry/ brand name
Fresh yeast	Cream yeast	Liquid form of the baker's yeast having solids content varying between 15-20% having no residual salt and starch.	Used in baking industry having extraordinary high-volume dispensing & blending equipment.	Abmauri, Bengaluru (India)
	Compressed yeast	Profoundly perishable and often used for long by veteran cooks; More tolerant of low temperatures than the most commercial yeasts.	Exceptionally flexible and performs well in the vast majority of the recipes.	Goodrich Carbohydrates, Haryana (India)
Dry yeast	Active dry yeast	Type of yeast accessible to non-commercial bread makers, having shelf life of months.	Used in home cooking due to long shelf life.	Blue Bird Foods, Mumbai (India)
	Instant dry yeast	It is like ADY, but has smaller granular form with high number of live cells. It is more perishable.	Used in home cooking but can be mixed directly with dough ingredients.	Goodrich Nutriesters, Delhi (India)
	Rapid rise yeast	Have smaller granular size, mixes quickly in dough, and generates CO_2 permitting quicker rising	Used in quicker bread manufacturing.	Sumathi Agro Industries, Bengaluru (India)
	Deactivated yeast (Nutritional yeast)	It is eaten as nourishing supplement consisting of proteins, B-complex vitamins and minerals required for proper development.	Used as toppings to eatables.	Urban Platter, Mumbai (India)

high ethanol profitability, high ethanol resistance and capacity to ferment extensive variety of sugars. Hybrid, wild-type and recombinant yeast strains are presently used in bioethanol production.

4. CRUCIAL ROLE IN BREAD MAKING

Yeast-mediated dough fermentation is an important phase in bread making process. Baker's yeast is used as a leavening agent in bread baking and many other products like cookies, pastries, crackers, tarts, etc. on whole known as baking products. It converts simple fermentable sugars in dough to CO_2 and ethanol. In addition, other metabolites are also produced which include glycerol and organic acids along with some aroma compounds. Fermentation by yeast leads to the expansion of dough, dough maturation and development of characteristic flavours in cereal-based products. The demand of yeast has grown exponentially as manufacture of fermented products increased after industrialization. Toward the end of the 19thcentury, expansion of exogenous yeast biomass to manufacture bread and lager began to end up a typical practice (Gómez-Pastor *et al.,* 2011). In the creation of baked goods, yeast is a key ingredient and serves in essential ways: i) Texture development: Yeast generate CO_2 gas which raises dough; giving bread a porous structure, ii) Increase of dough volume: The use of *S. cerevisiae* as leavening agent aids in achieving a good increase in the volume of bread. This implies that there is no more need to depend on egg white froth to enclose enough air, and iii) Flavour production: Baker's yeast accounts for the kind of bread and other yeast-raised items. During dough maturation, numerous auxiliary metabolites *viz.*, ketones, higher alcohols, natural acids, aldehydes and esters are formed by yeast. Some of these alcohols escape amid baking. Others show reaction with each other and with different compounds found in dough to shape new and more intricate flavours. The resultant flavour diffuses into the crumbs of bread.

Effective strain should be able to ferment sugar vigorously and grow rapidly resulting in the production of CO_2. With reference to dough leavening ability, it should be able to impart good aroma and sweetness the dough. Moreover, it should be able to grow rapidly during early fermentation and accelerated in early phase of baking to form oven spring (abrupt increase in volume of baked product before they are killed by oven heat) (Wu *et al.,* 2009).

5. BAKER'S YEAST AS PROBIOTICS

Yeasts have demonstrated beneficial impacts on human health (FAO, 2002). Among these, probiotic effects are the most surely understood welfare impacts including counteractive action and treatment of intestinal disorders and immunomodulatory impacts. FAO has characterized probiotics as "live microorganisms which when administered in adequate amounts confer a health benefit on the host" (Coté and Buchman, 2006). Antibiotic treatment is notable to destroy the ordinary bacterial population of gastrointestinal tract, which enables harmful microbes to settle and upset the host gut, leading to the antibiotic related diarrhea (Newberry, 2012). Earlier in history, probiotics were utilized just in animal feed. Various clinical studies have demonstrated the helpful impacts of *S. cerevisiae* var. *boulardii* in counteracting antibiotic related loose bowels (Cindoruk *et al.,* 2007; Whelan, 2007; Rajkowska *et al.,* 2012). Depicted in 1984 a saprophytic yeast, *S. cerevisiae* var. *boulardii* has been raised as a probiotic species for human utilization (Moslehi-Jenabian*et al.,* 2010). This strain has likewise been prescribed for the counteractive action and treatment of various kinds of gastroenteritis in youngsters and grown-ups (Jach *et al.,* 2015). Etienne-Mesmin *et al*. (2011) *in vitro* examined the probiotic impact of *S. cerevisiae* against *E. coli* O157:H7 and reported that probiotic yeast showed adverse impacts in distal piece of small intestine, perhaps because of ethanol generation. Probiotic yeast can be used in fermented products to increase their nutritional value or they can be directed orally as nutritional yeast, for patients who have been hospitalized due to extreme diarrhea. A few yeast species including *Torulasporadel brueckii* (Kumura *et al*., 2004; Psani and Kotzekidou, 2006), *Kluyveromyces lactis*, *Yarrowia lipolytica* (Chen *et al.,* 2010) and *K. marxianus* have been found strongly hostile to pathogenic microorganisms and endure passage through gastrointestinal tract. *S. boulardii* is considered probiotic and its probiotic activity has been reported in various clinical studies (Czerucka *et al.,* 2007; Kelesidis and Pothoulakis, 2011).

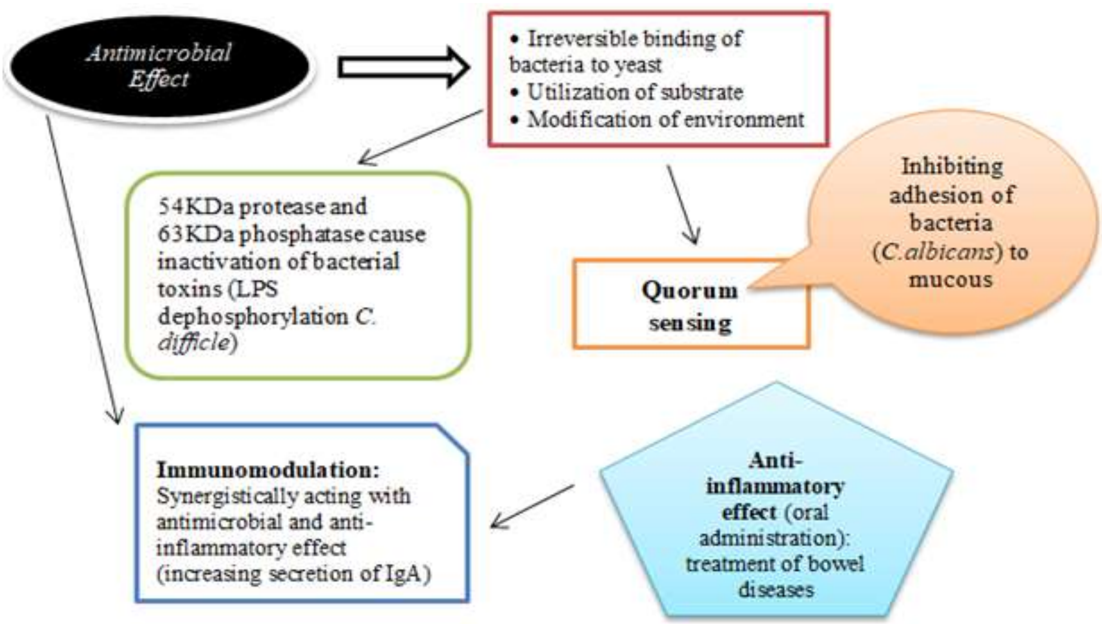

Fig. 2: *Saccharomyces boulardii*; Probiotic mechanism of action

Yeasts reportedly are resistant to antibiotics, safe to colonize intestine quickly by inhibiting enteric bacterial pathogens with anti-inflammatory effect, antagonistic towards gastro-intestinal (GI) pathogens and helpful in maintaining the epithelial barrier integrity so do not persist permanently in intestine which make them most suitable in GI tract (Moslehi-Jenabian *et al.,* 2010). Besides yeasts have other beneficial functions such as dephosphorylation of phytate, folate biofortification of foods and degradation of mycotoxins (Vilela *et al.,* 2008; Hjortmo *et al*., 2008; Olstorpe *et al.,* 2009).

6. BAKER'S YEAST AS HEALTH SUPPLEMENT

Prepared bread is rich source of carbohydrates (insoluble fibers, starch), B-complex vitamins (important for normal cellular growth and development) and minerals (for growth, development, energy metabolism and proper functioning of reproductive system). Commercial yeast has 40-50% protein and is a rich source of vitamin B that provide thiamine (B_1), riboflavin (B_2), niacin (B_3), pantothenic acid (B_5), pyridoxine (B_6), folic acid (B_7); beneficial for healthy nails, skin and hairs. Of these niacin helps to treat chronic acne while folic acid prevents birth defects (Moyad, 2008). Baker's yeast as a good source of vitamin B and chromium helps in maintaining normal blood sugar level and has been studied broadly for its pharmaceutical properties (Moyad, 2008). The commercial bread making yeasts (*S. boulardii* or *S. cerevisiae*) have been used as a potential biotherapeutic source in aggregation with standard anti-microbials for the treatment of *Clostridium difficile*-related diarrhea and colitis (Selinger *et al.*, 2013). As vitamins B source, *S. cerevisiae* strains can cure depression, fractiousness, stress, weakness and mitigate a few consequences of aging, enhance energy level and strengthen immune system (McFarlin *et al.*, 2017). Similarly, as biotin source they can reinforce hair and nails and treat cradle cap and diabetes neuropathy (Hosseinzadeh *et al.*, 2013). As chromium source, yeasts decrease glucose levels in patients with type 2 diabetes by improving glucose tolerance, relieve danger of elevated cholesterol in blood and help in acne and boil treatment (Jach *et al.*, 2015).

Activity	Yeast species	Health effects
Probiotic effect	*Saccharomyces cerevisiae* var. *boulardii*	1. Effects enteric bacterial pathogen (Czerucka *et al.*, 2000), 2. Anti-inflammatory effects (Dahan *et al.*, 2003), 3. Effects immune response (Rodrigues *et al.*, 2000), 4. Clinical effects on diarrheal disease (Vilela *et al.*, 2008)
Biodegradation of phytate	*S. cerevisiae, Rhodotorula gracilis, Torulaspora*	Nutritional importance i.e. bioavailability of minerals such as Fe, Zn, Ca and Mg (Olstorpe *et al.*, 2009)
Folate biofortification	*S. cerevisiae, S. bayanus* and *S. paradoxus*	Prevention of neural tube defects in the foetus and decreases the risk for cardiovascular disease, cancer and Alzheimer's disease (Hjortmo *et al.*, 2008)
Degradation of mycotoxins	*S. cerevisiae*	Antitoxic (Garda *et al.*, 2005)

Fig. 3: Health promoting activities of baker's yeast (*Saccharomyces cerevisiae*)

S. cerevisiae is sold and consumed as dietary supplement referred to as nutritional yeast which is rich in proteins, B-complex vitamins, minerals and cofactors required for growth and development. It is additionally low in fats and sodium. Nutritional yeasts have cheesy, nutty flavour that make them well known as cheddar substitutes. These are likewise utilized as topping for popcorns, French fries and additionally in fried eggs (Lallemand, 2011).

7. BAKER'S YEAST AS ANTI-CANCEROUS AGENT

Chemotherapy is presently the pillar of treatment for nearly all kinds of cancer, with agents applying their anticancer impact by provoking apoptosis (Ghoneum*et al.*, 2007). Researchers have investigated the potential of nonpathogenic baker's yeast in natural therapy of cancer and found the ability of heat-killed *S. cerevisiae* to promote apoptosis in human cancer cell lines (Ghoneum *et al.*, 2007). The phagocytosis of yeast reportedly promoted apoptosis in different human malignant cell lines *viz*., breast cancer-cells (BC-cells), tongue squamous cell carcinomas and colon adeno-carcinomas (Badr El-Din *et al.*, 2017). It was revealed that intra-tumoral infusion with *S. cerevisiae* causes apoptosis in BC (MCF-7 cells) bearing bare mice. This perception may have future restorative implication (Ghoneum and Gollapuri, 2004). The specificity, safety and ease of heat-killing non-pathogenic yeast may make it an effective and acceptable anti-cancer agent.

The cell wall of *S. cerevisiae* represents 10–25% of dry cell weight and comprises for the most part of β-glucans and mannan. The β-glucans which are isolated into β-1,3-glucan and β-1,6-glucan constitute 50–60% of cell mass dry weight (Aguilar-Uscanga and Francois, 2003). Since the physiological capacity of β-glucans is to stimulate immune cells, their utilization to upgrade resistance is well demonstrated (Ikeda *et al.*, 2008). Zymosan, a molecule containing β-glucans from *S. cerevisiae*, can initiate a mouse macrophage and creation of cytokines, for example, tumour necrosis factor-α (TNF-α) (Young *et al.*, 2001).

8. BAKER'S YEAST IN BIOREMEDIATION

Substantial metal contamination has been a genuine concern natural issue (Bahafid *et al.*, 2007). However, million tons of polluting lethal metals such as Hg, Mn, Cd, Zn, Pb, As, Cu, Ni, etc. are directly or indirectly discharged into the natural environment (Nancharaiah *et al.*, 2016). The real challenge is to create innovative and profitable solution to clean contaminated environments and ensure proper and balanced functioning of biological communities. Volesky (1994) short-listed some accessible techniques for evacuating the dissolved substantial metals including synthetic precipitation, filtration, reduction, oxidation, ion exchange, evaporation, reverse osmosis, membrane technology and electrochemical treatment. However, most of these methods are noticeably incapable when the concentrations of these metals are < 100 mg L^{-1} (Ahluwalia and Goyal, 2007). Further, the powerful and polluting reagents are employed leading to auxiliary environmental contamination (Anushree, 2004). Yeast cells are amongst the most universal biomass types accessible for bioremediation of substantial metals that have the capacity to scavenge a wide range of heavy metals to varying degrees under broad range of extensive conditions (Abbas and Badr, 2015). Knowledge about metal detoxification methods employed by yeasts is presently less available as compared to prokaryotes. The most considered yeast for metal detoxification is placed under ascomycetes like *S. cerevisiae*, *S. pombe* and *Candida* spp. (AssisFidalgo, 2011). Yeasts reportedly have developed a few distinctive detoxifying methods to immobilize, assemble or transform metals. The yeast bioremediation mechanisms include immobilization and mobilization techniques (Fig. 4). Immobilization techniques include:

- ✓ <u>Bioaccumulation</u>: This involvesintracellular uptake of metal ions by living cells.
- ✓ <u>Biosorption</u>: This involves the interaction of metals with cell membrane via different processes like ion exchange, adsorption crystallization and precipitation.
- ✓ <u>Biotransformation</u>: Toxic metals are converted to less toxic or harmless form.

Mobilization techniques include;

- ✓ <u>Bioleaching</u>: Acids are produced which interact with metal ions to produce insoluble complexes.

9. CONSTRAINTS AND FUTURE PROSPECTS

S. cerevisiae is the most essential fermentation microorganism based on its wide application in bread making. New food products with better and sophisticated properties make the search for new and improved industrial strains a promising task. Among these sophisticated ready to use products, frozen dough is gaining considerable attention. Therefore, the development of freeze-tolerant *S. cerevisiae* is of great economic interest. There is need to improve freeze tolerance of baker's yeast by using different strategies to fulfill the requirements of ever-growing population. Yeast biomass can not only

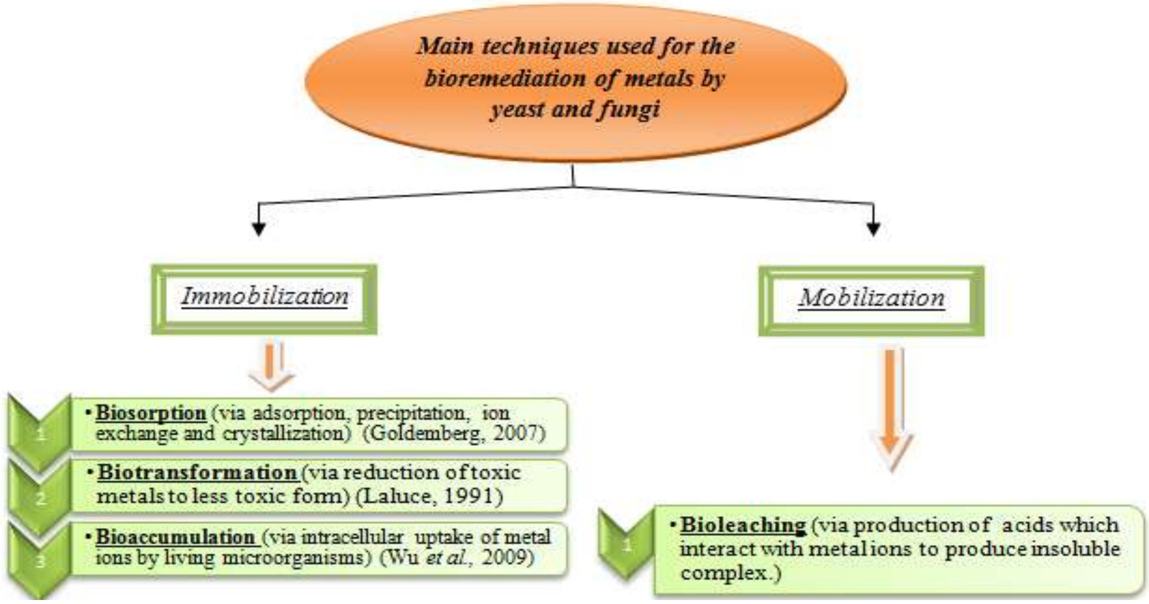

Fig. 4: Environmental applications of baker's yeast

be used for baking but its dried formulations can be prepared and used as nutritional yeast after testing for required parameters.

Different strains of yeasts (*S. cerevisiae*, *S. exiguous* and *S. boulardii*) are used in food and pharmaceutical industry. It is a source of vitamin B, minerals and proteins and may serve as a health supplement. Beta-glucan fiber from yeast cell wall has been reported to be better than oats fiber. As probiotic, it plays a role in folate biofortification, detoxification and increasing bioavailability of nutrients. It has been reported to have anti-cholesterolemic, anti-mutagenic, anti-oxidative and anti-tumor potential. It has crucial role in bioethanol production and bioremediation. Many of these processes are being exploited, while others are under development.

REFERENCES

Abbas, B.A. and Badr, S.Q. 2015. Bioremediation of some types of heavy metals by *Candida* spp. *International Journal of Engineering and Technical Research*, **3**: 2454-4698.

Aguilar-Uscanga, B. and Francois, J.M. 2003. A study of the yeast cell wall composition and structure in response to growth conditions and mode of cultivation. *Letters in Applied Microbiology*, **37**: 268-274.

Ahluwalia, S.S. and Goyal, D. 2007. Microbial and plant derived biomass for removal of heavy metals from wastewater. *Bioresource Technology*, **98**: 2243-2257.

Al-Farsi, M., Alasalvar, C., Al-Abid, M., Al-Shoaily, K., Al-Amry, M. and Al-Rawahy, F. 2007. Compositional and functional characteristics of dates, syrups and their by-products. *Food Chemistry*,**104**: 943-947.

Anushree M. 2004. Metal bioremediation through growing cells. *Environment International*, **30**: 261-278.

Assis Fidalgo, C.I. 2011. *Heavy Metal Resistance in Extremophilic Yeasts: A Molecular and Physiological Approach*. M.Sc. thesis, Department of Plant Biology, Science College, University of Lisbon, Lisbon, Portugal.

Badr El-Din, N.K., Mahmoud, A.Z., Hassan, T.A. and Ghoneum, M. 2017. Baker's yeast sensitizes metastatic breast cancer cells to paclitaxel *in vitro*. *Integrative Cancer Therapies*, **17**: 542-550.

Bahafid, W., Joute, N.T., Asri, M., Sayel, H., Tirry, N., Joutey, N.E.T., Asri, M., Sayel, M., Tirry, N. and Naïma El Ghachtouli. 2007. Yeast biomass: An alternative for bioremediation of heavy metals. pp. 269-289. In: *Yeast - Industrial Applications*. INTECH Open Access Publisher, London, UK.

Basso, L.C., Henrique, V., de Amorim., Antonio, J., de Oliveira., Mario, L. and Lopes. 2008. Yeast selection for fuel ethanol production in Brazil. *FEMS Yeast Research,* **8**: 1155-1163.

Bekatorou, A., Psarianos, C. and Koutinas, A. 2006. Food grade yeasts. *Food Technology and Biotechnology,* **44**: 407-415.

Chen, L.S., Ma, Y., Maubois, J.L., He, S.H., Chen, L.J. and Li, H.M. 2010. Screening for the potential probiotic yeast strains from raw milk to assimilate cholesterol. *Dairy Science Technology,* **90**: 537-548.

Cindoruk, M., Erkan, G., Karakan, T., Dursun, A. and Unal, S. 2007. Efficacy and safety of *Saccharomyces boulardii* in the14-day triple anti-*Helicobacter pylori* therapy: A prospective randomized placebo-controlled double-blind study. *Helicobacter,* **12**: 309-316.

Coté, G.A. and Buchman, A.L. 2006. Antibiotic-associated diarrhoea. *Expert Opinion on Drug Safety,* **5**: 361-372.

Czerucka, D., Piche, T. and Rampal, P. 2007. Review article: Yeast as probiotics – *Saccharomyces boulardii*. *Alimentary Pharmacology and Therapeutics,* **26**: 767-778.

Erdeve, O.; Tiras, U. and Dallar, Y. 2004. The probiotic effect of *Saccharomyces boulardii* in a pediatric age group. *Journal of Tropical Pediatrics,* **50**: 234-238.

Etienne-Mesmin, L., Livrelli, V., Privat, M., Denis, S., Cardot, J.M., Alric, M. 2011. Effect of a new probiotic *Saccharomyces cerevisiae* strain on survival of *Escherichia coli* O157:H7 in a dynamic gastrointestinal model. *Applied and Environmental Microbiology,* **77**: 1127-1131.

FAO. 2002. *Guidelines for the Evaluation of Probiotics in Food*. Food and Agriculture Organization of the United Nations, London/Ontario, Canada.

Ghoneum, M. and Gollapudi, S. 2004. Induction of apoptosis in breast cancer cells by *Saccharomyces cerevisiae*, the baker's yeast, *in vitro*. *Anticancer Research*, **24**: 1-29.

Ghoneum, M., Wang, L., Agrawal, S., Gollapudi, S. 2007. Yeast therapy for the treatment of breast cancer: A nude mice model study. *In vivo,* **21**: 251-258.

Goldemberg, J. 2007. Ethanol for a sustainable energy future. *Science*, **315**(5813): 808-810.

Gómez-Pastor, R., Pérez-Torrado, R., Garre, E. and Matallana, E. 2011. Recent advances in yeast biomass production. pp. 201-222. **In**: *Detection, Production and Usage* (ed. D. Matovic). INTECH Open Access Publisher, London, UK.

Hatoum, R., Labrie, S. and Fliss, I. 2012. Identification and partial characterization of antilisterial compounds produced by dairy yeasts. *Probiotics and Antimicrobial Proteins,* **3**:1-10.

Hjortmo, S.B., Hellstrom, A.M. and Andlid, T.A. 2008 Production of folates by yeasts in Tanzanian fermented togwa. *FEMS Yeast Research*, **8**: 781-787.

Hoekman, S.K. 2009. Biofuels in the U.S. – Challenges and opportunities. *Renewable Energy*, **34**: 14-22.

Hosseinzadeh, P., Djazayery, A., Mostafavi, S.A., Javanbakht, M.H., Derakhshanian, H., Rahimiforoushani, A., and Djalali, M., 2013 Brewer's yeast improves blood pressure in type 2 diabetes mellitus. *Iranian Journal of Public Health*, **42**: 602-609.

Ikeda, Y., Adachi, Y., Ishii, T., Miura, N., Tamura, H. and Ohno, N. 2008. Dissociation of Toll-like receptor 2-mediated innate immune response to Zymosan by organic solvent-treatment without loss of Dectin-1 reactivity. *Biological and Pharmaceutical Bulletin,* **31**: 13-18.

Jach, M.E., Serefko, A., Sajnaga, E., Kozak, E., Poleszak, E. and Malm, A. 2015. Dietary supplements based on the yeast biomass. *Current Topics in Nutraceutical Research*, **13**: 83-88.

Johnson, E.A. and Echavarri-Erasun, C. 2011. Yeast biotechnology. pp. 21-44. **In**: *The Yeasts, A Taxonomic Study* (5^{th} edn) (eds. C. Kurtzman, J.W. Fell and T. Boekhout). Elsevier Science, Amsterdam, Netherland.

Kelesidis, T. and Pothoulakis, C. 2011. Efficacy and safety of the probiotic *Saccharomyces boulardii* for the prevention and therapy of gastrointestinal disorders. *Therapeutic Advances in Gastroenterology,* **5**(2): 111-125.

Kumura, H., Tanoue, Y., Tsukahara, M., Tanaka, T. and Shimazaki, K. 2004. Screening of dairy yeast strains for probiotic applications. *Journal of Dairy Science*, **87**: 4050-4056.

Lallemand Baking Update. 2011. *Yeast Characteristics. Practical Technology*. Lallemand Inc., Montréal, Canada

McFarlin, B.K., Henning, A.L., Bowman, E.M., Gary, M.A. and Carbajal, K.M. 2017. Oral spore-based probiotic supplementation was associated with reduced incidence of post-prandial dietary endotoxin, triglycerides and disease risk biomarkers. *World Journal of Gastrointestinal Pathophysiology,* **8**(3): 117-126.

Moyad, M.A. 2008. Brewer's/Baker's yeast (*Saccharomyces cerevisiae*) and preventive medicine: Part II. *Urologic Nursing*, **28**: 73-75.

Moslehi-Jenabian, S., Lindegaard, L., Pedersen and Jespersen, L. 2010. Beneficial effects of probiotic and food-borne yeasts on human health. *Nutrients*, **2**: 449-473.

Nancharaiah, Y.V., Mohan, S.V. and Lens, P.N.L. 2016. Biological and bioelectrochemical recovery of critical and scarce metals. *Trends in Biotechnology,* **34**: 137-155.

Newberry, S.J. 2012. Probiotics for the prevention and treatment of antibiotic-associated diarrhea. *The Journal of American Medical Association,* **307**: 1959-1969.

Olstorpe, M., Schnurer, J. and Passoth, V. 2009. Screening of yeast strains for phytase activity. *FEMS Yeast Research*, **9**: 478-488.

Perera, F. 2017. Pollution from fossil-fuel combustion is the leading environmental threat to global pediatric health and equity: Solutions exist. *International Journal of Environmental Research and Public Health*, **15**: 15-16.

Psani, M. and Kotzekidou, P. 2006. Technological characteristics of yeast strains and their potential as starter adjuncts in Greek style black olive fermentation. *World Journal of Microbiology and Biotechnology,* **22**: 1329-1336.

Rajkowska, K., Kunicka-Styczynska, A. and Rygala, A. 2012. Probiotic activity of *Saccharomyces cerevisiae* var. *boulardii* against human pathogens. *Food Technology and Biotechnology,* **50**: 230-236.

Richard, C. 2006. Brazil: A world leader. *Sugar Journal*, **69**: 11-15.

Selinger, C.P., Bell, A., Cairns, A., Lockett, M., Sebastian, S. and Haslam, N. 2013. Probiotic VSL#3 prevents antibiotic-associated diarrhoea in a double-blind, randomized, placebo-controlled clinical trial. *Journal of Hospital Infection,* **84**: 159-165.

Van der Walt, J.P. 1970. *Kluyveromyces* van der Walt emend van der Walt. Pp. 1059-67. **In**: *The Yeasts: A Taxonomic Study* (2nd edn) (ed. J. Lodder). North Holland Publishing Co., Amsterdam, Netherlands.

Vilela, E.G., Ferrari, M.D.D., Torres, H.O.D., Pinto, A.G., Aguirre, A.C.C., Martins, F.P., Goulart, E.M.A. and Da Cunha, A.S. 2008. Influence of *Saccharomyces boulardii* on the intestinal permeability of patients with Crohn's disease in remission. *Scandinavian Journal of Gastroenterology,* **43**: 842-848.

Volesky B. 1994. Advances in biosorption of metals: Selection of biomass types. *FEMS Microbiology Review*, **14**: 291-302.

Whelan, K. 2007. Enteral-tube-feeding diarrhoea: Manipulating the colonic microbiota with probiotics and prebiotics. *Proceedings of Nutrition Society*, **66**: 299-306.

Wu, Q., Jezkova, A., Yuan, Z., Pavlikova, L., Dohnal, V. and Kuca, K. 2009. Biological degradation of aflatoxins. *Drug Metabolism Reviews,* **41**: 1-7.