

DIETARY SUPPLEMENTS BASED ON THE YEAST BIOMASS

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ABSTRACT: *Regarding an increase in consumption of yeasts in a form of dietary supplements, we decided to review briefly some of their properties that may be of particular importance for human health. Saccharomyces cerevisiae, that have been demonstrated to exert health-promoting effects due to their rich vitamin (especially B-complex) and mineral content, as well as their role in the production of microbial proteins, β-glucans and mannans. Hence, the intake of brewer's yeasts as a nutritional supplement is popular among vegans and health conscious people. Furthermore, several species of yeasts possess the properties required for a microorganism to be considered as probiotic. The available yeast supplements contain specific strains of S. cerevisiae, sometimes in combination with lactic acid bacteria. They may be beneficial for diabetic patients and display cancer-preventive properties. The relatively unknown Yarrowia lipolytica deserves particular attention, since it contains highly bioavailable proteins, essential amino acids, minerals, and polyunsaturated fatty acids. The objective of this paper is to review the beneficial health properties of dietary supplements based on S. cerevisiae and other related species, e.g. Y. lipolytica.*

KEY WORDS: Dietary supplements; Saccharomyces cerevisiae; Yarrowia lipolytica; Yeast

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INTRODUCTION

Yeasts can be considered the oldest industrial microorganisms

used by humans. Yeasts attracted the attention because of their multiple health effects and industrial applications (i.e., as the dietary supplements with a high nutritional value or as the yeast extracts). *Saccharomyces cerevisiae* (known also as the brewer's yeasts or baker's yeasts) is one of the well-known and commercially significant yeast species. The brewer's yeasts have Food and Drug Administration GRAS (Generally Regarded/Recognized As Safe) status and therefore they are considered as safe. The brewer's yeasts are often used as an abundant source of a vitamin B complex, including B1 (thiamine), B2 (riboflavin), B3 (niacin), B5 (pantothenic acid), B6 (pyridoxine), B9 (folic acid), and B7 (biotin) (Moyad 2007; Moyad 2008), which plays an important role in human body. These essential nutrients help to convert the ingested food into fuel, allowing the human organism to stay energized throughout the day. While all of the B vitamins work together to maintain good health, each of them has its own specific benefits - from promoting healthy eyes, heart, liver, skin, nails, and hair to preventing memory loss or migraines. B vitamins also support the nervous system and help to maintain the smooth muscles of the digestive tract (Moyad 2008). It is worth mentioning that the brewer's yeasts do not contain vitamin B12. However, vegetarians whose diet is poor in vitamin B12 often consume them mistakenly hoping that the brewer's yeasts will compensate for the lack of meat in their daily diet (Moyad 2007; Moyad 2008).

The brewer's yeasts and other non-conventional yeasts like *Yarrowia lipolytica* contain highly bioavailable proteins (Groenewald et al., 2013; Moyad 2008) and several essential amino acids (Kamzolowa et al., 2012). Therefore, they may be used as protein supplements and energy boosters (Moyad 2008). The brewer's yeasts (but not the baker's yeasts) and *Y.*

lipolytica are also rich in oligoelements and minerals, particularly in chromium and selenium (Dobrzański et al., 2003; Moyad 2008). It is alleged that the selenium-enriched yeasts protect proteins, lipids, and DNA from the oxidative damage, and support the normal function of the immune system, thyroid hormone as well as the undisturbed spermatogenesis (EFSA 2006). The results of several studies suggest that chromium supplements, especially those containing the organic compounds/complexes and regarded as more bioavailable, may be beneficial for diabetic patients who either do not produce enough insulin or cannot use the secreted insulin properly. Chromium may help them to keep sugar levels under control, improve glucose tolerance, and reduce the required amount of insulin (Moyad 2008). Yeasts are also known to contain other essential microelements that participate in the physiological and metabolic processes in human organism, such as Zn, Cu, Mn (Barbulescu et al., 2010), Fe (Pirman and Oresnik 2012), and Mg (Guo et al., 2011).

In order to manufacture a yeast formulation rich in bioavailable organic forms of microelements, the yeasts should be cultured in a medium supplemented with a selected mineral (Cr, Se, Mg, Cu, Zn, Mn etc.). Cultivating the yeasts in a selenium-rich media produces the so-called selenium-enriched yeasts. Yeasts absorb the inorganic Se compounds from the culture medium and convert it into selenomethionine (Schrauzer 2006) that enters the food chain of the higher animals and humans. Selenomethionine, not synthesized by humans, fulfills the criteria of an essential amino acid (Schrauzer 2003) and can replace methionine in proteins (Jacobson 2010).

The brewer's yeasts contain a high level of polysaccharides, such as β -glucans (Rahar et al. 2011) and mannans (Corrigan et al., 2011). Glucans and glycoproteins are the main components of a layered fungal cell wall. β -glucans can be found in over ten different yeasts (Rahar et al., 2011), including *Y. lipolytica* (Esteban et al., 1999). β -glucans influence the absorption of sugars and reduce levels of serum lipids (Rahar et al., 2011), and as a result they help to lower the risk of obesity and cardiovascular diseases (Chen and Raymond 2008).

According to the literature data (Weber et al., 1989), *S. cerevisiae* brewer's yeasts (i.e., Hansen CBS 5926 strain) are also effective in patients with acne, especially as an alternative treatment in the case of acne-related skin problems. Moreover, the immune-supporting properties of the brewer's yeasts have been confirmed in clinical trial. Significant reduction of symptoms associated with the seasonal suppression of the immune system was noted in patients receiving EpiCor (Moyad 2008).

SACCHAROMYCES CEREVISIAE AS A DIETARY SUPPLEMENT

The dietary supplements market is abundant in products containing the brewer's yeasts rich in minerals and vitamin B complex as well as in valuable amino acids, glucans and mannans (Table 1). They are usually in a form of powder (administered after suspension in food or a small amount of water or juice), capsules, tablets or in a liquid form. Herbal raw ingredients (i.e.,

mint, lemon balm, horsetail, nettle) or vitamins A, C, and E are frequently added to these preparations. Brewer's yeasts can also be found in foodstuffs, such as fermented milk. The pure yeast beverages are popular as well. However, it is generally recommended to take regular breaks from using dietary supplements. Besides, the products containing high amount of proteins can burden the kidneys, thus it is not advisable to use them continuously (Delimaris 2013).

TABLE 1. The dietary yeast supplements and their benefits.

Yeast supplements	Indications
Brewer's yeasts, Magnesium stearate	Slimming diet, fatigue, weakness, skin, nails, and hair problems.
<i>S. cerevisiae</i> , Zinc, vitamins: B1, B2, B3, B5, B6	Oily and combination skin, deterioration of skin condition, hair thinning, weaken fingernails particularly in mature women.
<i>S. cerevisiae</i> , Flower pollen extract, Vitamins: B1, B2, Phosphor, Magnesium, Potassium, Calcium, Zinc	During the intensive growth in adolescence, fatigue caused by an unbalanced diet and tiredness, skin problems; supports healthy metabolism.
<i>S. cerevisiae</i> , Vitamins: A, C, E	Beneficial for skin, hair, and nails. Prevents the development of cheilosis and seborrhoea, improves the metabolic processes, and supports the immune system particularly in heavy smokers, high-fat consumers, elderly people, and convalescents.
Brewer's yeast, Horsetail (extract), Nettle (extract)	Fragile and brittle nails, excessive hair loss. Beneficial for skin and mucous condition; facilitates the excretion of waste products from the body.
<i>S. cerevisiae</i> , Horsetail (extract), Nettle (extract), D-biotin, Whey protein complex	Beneficial for hair and nails. Adjunctive treatment in acne vulgaris.
<i>S. cerevisiae</i> , Vitamins: B1, B2, B3, Flower bee pollen, Chromium	General fatigue, loss of appetite, skin problems (acne, eczema, furunculosis, cracked corners of the mouth, complexion problems in adolescence), hair problems (excessive hair loss), and nail problems. Facilitates the metabolic processes (metabolism of carbohydrates, fats and proteins) and supports the immune system.
<i>S. cerevisiae</i> , Vitamins: B1, B2, B3, Biotin, Phosphorus, Potassium, Powdered angelica root	Beneficial for nervous system, skin, hair, and nails. Facilitates digestion and relieves migraine pain; in general fatigue, exhaustion, and as a stimulant of the immune system.

<i>S. cerevisiae</i> , Vitamins: B1, B2, B3, Chromium, Powdered mint leaf	General fatigue, exhaustion, weakened immune system, skin problems, hair loss, and brittle nails. Beneficial for gastrointestinal tract (increases the secretion of digestive juices and eliminates flatulence).
Brewer's yeast, Vitamin B12	Particularly for vegetarians and vegans as supplementation of B vitamins.
Yeast extract, Viola tricolor herb extract, Vitamin E, Organic zinc	Beneficial for skin (particularly in adolescence), hair, and nails.
Brewer's yeast, Selenium's yeast, Zinc oxide	Supports the immune system, fights free radicals, prevents premature aging, protects heart and the circulatory system.
<i>S. cerevisiae</i> , Flower pollen, Zinc, Pantothenic acid, Vitamins: B1, B2, Folic acid, Selenium	Fatigue and exhaustion, skin problems, hair loss, and brittle nails.
<i>S. cerevisiae</i> , Vitamins: B1, B2, B6, Nicotinic acid, Pantothenic acid, Folic acid	Beneficial for lipid metabolism, skin and hair. Calming effect and the prebiotic properties (towards the intestinal bacteria <i>Lactobacillus</i>). Elimination of the toxic components (i.e., <i>E. coli</i> , <i>Salmonella</i> , mycotoxins) from the body.
Lyophilized of probiotic bacteria strains: <i>Lactobacillus acidophilus</i> Rosell-52, <i>Lactobacillus rhamnosus</i> Rosell-11, <i>Bifidobacterium longum</i> Rosell-175, Zn- and Se-enriched yeasts	Weakened immunity, increased susceptibility to viruses and bacteria, antibiotic therapy.

It is necessary to mention that the brewer's yeasts are not recommended for everyone. They should be particularly contraindicated for individuals suffering from inflammatory bowel disease (e.g. ulcerative colitis, Crohn's disease) (Nenoff et al., 2001), glaucoma, and hypertension. Consumption of the brewer's yeasts may aggravate the existing illness. Moreover, people who frequently suffer from yeast infections or who are allergic to yeasts should avoid the dietary supplements based on the brewer's yeast biomass.

The brewer's yeasts contain a large amount of tyramine, i.e., a substance that can interact with monoamine oxidase inhibitors (MAOIs). After taking the preparations of brewer's yeasts and MAOIs concomitantly, the so-called hypertensive crisis (i.e., a rapid and severe increase in blood pressure) may occur and it may result in a heart attack or stroke. Since the brewer's yeasts are known to affect glucose metabolism, the diabetic patients should call for medical advice before taking the brewer's yeast preparations (Moyad 2008).

Although there is little research evidence to prove that the consumption of yeast formulations may contribute to the development of gout, careful consideration should be given to the predisposed patients when recommending to them the dietary supplements or foodstuffs rich in nucleic acids (including nucleic acids from fungi) (Chen and Schumacher 2008). The literature data indicate that following the consumption of the brewer's yeasts by the individuals hypersensitive to the biogenic amines, migraine, skin irritation, redness, and swelling may occur (Nenoff et al., 2001). Though the side effects of the dietary supplements containing the brewer's yeasts are generally mild, these preparations are primarily intended for adults. There is no sufficient data regarding their safety in children (Moyad 2008).

YEAST SUPPLEMENTATION IN DISORDERS OF GLUCOSE METABOLISM

According to the available literature, selenium- and chromium-enriched yeast biomass exerts particularly beneficial effects on human health (Moyad 2007; Moyad 2008). Sherman et al. (1968) reported that chromium supplementation is not sufficient when given as the inorganic compounds that are very poorly (1-3%) absorbed. This fact should be of a special concern, since the disorders of glucose metabolism are observed in chromium deficiency (Stupar et al., 2007). The alterations of chromium metabolism were observed in diabetic patients and elderly people. According to the results of the laboratory tests, the chromium levels in hair, liver, and plasma are significantly lower in individuals suffering from diabetes. It is probable that insulin injections lead to the increased excretion of chromium from the human body (Morris et al., 1999).

The role of Cr ions in the metabolism of glucose in mammals is connected with the glucose tolerance factor (GTF), regarded as a natural anti-diabetic agent (Mirsky 2012). Though there are several sources of the GTF, the brewer's yeasts are particularly rich in the highly bioavailable form of this complex, providing the significant amount of easily absorbed organic form of chromium (Mirsky 2012; Weksler-Zengen et al., 2012). The GTF from yeasts exerts the remarkable insulin-mimetic and insulin-potentiating effects, observed both *in vivo* and *in vitro*. It is known to decrease the elevated blood sugar, reduce triglycerides, and LDL cholesterol levels as well as to increase HDL cholesterol level in diabetic subjects. The GTF administration also prevents diabetes complications such as nephropathy and retinopathy (Mirsky 2012).

The results of pre-clinical and preliminary clinical studies confirm the beneficial effect of yeast consumption in patients with disorders in glucose metabolism. However, only a long-term supplementation leads to a substantial improvement in disease indicators (Khosravi-Boroujeni et al., 2012). The experiments performed by Lai et al. (2006) revealed that chromium from yeasts significantly reduced the fasting glucose and LDL cholesterol level in rats with experimentally induced diabetes. An 8-week administration of the multi-mineral (i.e., Cr, Se and Zn-enriched) yeast biomass to the diabetic mice

resulted in a decrease in blood levels of glucose, triglycerides, and total cholesterol. Moreover, a simultaneous increase in HDL cholesterol fraction, blood glutathione, and activity of superoxide dismutase and glutathione peroxidase was observed. The protective effect on the pancreatic islets and no side effects of the treatment were also reported (Jun et al., 2012). Khosravi-Boroujeni et al. (2012) demonstrated that the consumption of brewer's yeasts for 8 weeks reduced the cardiometabolic risk in type 2 diabetic patients with hypercholesterolemia. There is an assumption that the components of the yeast biomass other than chromium may contribute to the observed beneficial effects on the cardiometabolic risk factors (Rajpathak et al., 2004). On the other hand, the expected hypoglycaemic benefits after supplementation with the chromium-enriched brewer's yeasts have not been observed in the studies conducted by Król et al. (2011).

YEAST SUPPLEMENTATION IN CANCER PROPHYLAXIS

The preliminary studies showed a link between an elevated selenium level after consumption of the Se-enriched yeasts and a reduced risk of developing cancer (Duffield-Lillico et al., 2002), including prostate (Clark et al., 1998), colorectal, lung, and nonmelanoma skin cancers (Jacobson 2010). However, the mechanism of this anti-cancer effect has not been fully understood. Several authors suggested that methyl selenol (a selenium metabolite) plays an important role in cancer prevention (Combs and Lu 2006). In a double-blind, randomized, placebo-controlled trial, after 9 months of consumption of the selenium-enriched yeasts, a significant increase in blood glutathione (GSH) along with a decrease in the free and protein-bound glutathione ratio (suggesting the reduction of oxidative stress) were observed. Moreover, a small and of short duration, but significant decrease in prostate-specific antigen level was recorded after 3 and 9 months of supplementation (El-Bayoumy et al., 2002). Hawkes et al. (2008) have not confirmed the supposition of the elevated risk of gaining weight after taking the dietary supplements based on the selenium-enriched yeasts as an anti-tumor prophylaxis.

In a double-blind, randomized, placebo-controlled clinical trial on nonmelanoma skin cancer prevention, selenium given in a form of the selenium-enriched yeasts was ineffective in preventing basal cell carcinoma in the high-risk individuals. Moreover, selenium supplementation increased the risk of squamous cell carcinoma and total nonmelanoma skin cancer (Duffield-Lillico et al., 2003).

THE NUTRITIONAL SUPPLEMENTS BASED ON OTHER YEAST SPECIES

Apart from *S. cerevisiae*, several other yeasts also appeared to be beneficial to human health thanks to their unique properties. One of them is a nonpathogenic *Y. lipolytica* species, successfully used in industry, particularly as a biocatalyst. Several processes involving *Y. lipolytica* were classified as GRAS (Groenewald et al., 2013; Kamzolowa et al., 2012). *Y.*

lipolytica is primarily found in food containing large amounts of fats and/or proteins, particularly in the fermented dairy products and meat (e.g. cheese, butter, cream, margarine, yoghurt, salami, Spanish fermented sausages). *Y. lipolytica* is able to accumulate large amounts of lipids, therefore, it may be used as a rich source of both the high-quality proteins (and amino acids), and the polyunsaturated fatty acids (especially the linoleic acid) (Groenewald et al., 2013). *Y. lipolytica* is also known as a rich source of minerals, particularly chromium and selenium (Musiał et al., 2005).

Apart from the well-known probiotic *Saccharomyces boulardii*, the beneficial properties of the lactic yeast traditionally grown on cheese whey, i.e., *Kluyveromyces marxianus*, have been examined. It has been shown that this microorganism has a potential to be considered as probiotic (Nenoff et al. 2001).

The beneficial health effects of the combination of yeasts and lactic acid bacteria are utilized in kombucha, a drink of a fermented and sweetened black tea. Several different species of yeasts were identified within the kombucha culture (including *Brettanomyces bruxellensis*, *Candida stellate*, *Schizosaccharomyces pombe*, *Torulaspora delbrueckii*, and *Zygosaccharomyces bailii*) (Tooh et al., 2004).

CONCLUSION

In recent years, yeasts have been used as nutritional supplements more frequently. The most well-known and commercially significant yeasts are *S. cerevisiae*, while other closely related species are of increasing interest. Yeast biomass has been found as an important starting material in pharmaceutical industry for production of dietary supplements, particularly recommended for vegans or vegetarians as well as for the young people who enter puberty. It is beyond dispute that yeasts, especially the brewer's yeasts, are a rich source of the bioavailable exogenous amino acids, microbial proteins, vitamins, and minerals. At the same time, they are low-sodium and low-fat. Some of the yeast-based preparations may be particularly appropriate for convalescents, people who want to build muscle or those who focus on maintaining healthy body weight. Patients with cancer or disorders in glucose metabolisms may benefit from selenium- or chromium-enriched yeasts, respectively. The deliberate use of yeasts in the diet opens new fields in the traditional technological processes and creates opportunities for the development of novel areas of both industry and science.

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