Saccharomyces cerevisiae var. boulardii as a eukaryotic probiotic and its therapeutic functions

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Abstract:
Fuller, in 1989, described probiotic microorganisms as “a live microbial feed supplement, which beneficially affects the host animal, by improving its intestinal microbial balance”. Saccharomyces cerevisiae var. boulardii (S.boulardii) is an accurate probiotic yeast idol. The detection and budding of S.boulardiiis firmly related to the impression of healthiness to promote microorganisms from foodstuff. S.boulardiiis similar to S.cerevisiae in that it equally does not have the capability to penetrate into tissues like the Candida species is able to, hence they are not invasive. Some printed medicinal researches have shown the effectiveness and safety of S.boulardii for different illness indications in both adults and children. On the subject of the therapy employed, diverse indications of S.boulardii are as follows: Anticipation of antibiotic related diarrhea, recurring Clostridium difficile related diarrhea and colitis, severe viral and bacterial diarrhea, travelers’ diarrhea, anti-inflammatory bowel syndromes as well as Crohn's disease and so on. These days, S.boulardii is regularly marketed as a probiotic in a lyophilized shape and is often referred to as S.boulardii lyo.

Keywords: Eukaryote, probiotic, therapeutic, yeast.

Introduction
The idea of probiotic microorganisms was offered and revealed through Élie Metchnikoff for its important value in the twentieth century. Originally, Metchnikov's hypothesis that lactic acid bacteria is able to extend life was arguable and some investigators doubted it (Floch, 2014; Guandalini, 2011; Lukaszewicz, 2012; Mirzaei et al., 2012). Cheplin and Rettger in 1920 confirmed that Metchnikov's strain, at present is termed Lactobacillus delbrueckii subsp. bulgaricus could not survive within the human intestinal tract (Lukaszewicz, 2012). A logical debate is required to help forge and define the quarreled suggestions. This innovative phrase was probiotically employed by Werner Kollath in 1953 to show the distinguishing effect to damaging antibiotics, as well as the entire superior organic and inorganic compounds present (Lukaszewicz, 2012). Fuller in 1989, described probiotic microorganisms as, “a live microbial feed supplement, which beneficially affects the host animal by improving its intestinal microbial balance” (Fuller, 1989; Lukaszewicz, 2012). Sandersin 1996, plainlydefined probiotics as, microbes used for healthiness effects (Lukaszewicz, 2012).
Amongst the effects of probiotics, are the following: increased foodstuff digestion and absorption (Gareau et al., 2010; Pourjafar et al., 2011; Soccol et al., 2010; Vohra and Satyanarayana, 2012; Zauouche et al., 2000), diminishing blood cholesterol (Krasowska et al., 2007; Mirzai et al., 2011; Soccol et al., 2010), having anti-inflammatory property (Cain and Karpa, 2011; Choi et al., 2011; Dalmasso et al., 2006; Generoso et al., 2011; Lee et al., 2009; Ng et al., 2010; Pathoulakis, 2009; Sougioultzis et al., 2006; Thomas et al., 2011), amplification of the immune system (Baumgart, 2007; Buts et al., 1990; Canonici et al., 2011; Czerucka and Rampal, 1999; Dalmasso et al., 2006; De Lianos et al., 2010; Fidan et al., 2009; Martins et al., 2010; Thomas et al., 2011) and antitumor results (Pourjafar and Ghasemnezhad, 2013), in addition to raising the body resistance in opposition to diseases (Floch, 2014; Gareau et al., 2010). Alternatively, they are manufactured today as a proper substitute for antibiotics in opposition to pathogenic substances in human beings and animals (Barc et al., 2008; Pourjafar and Ghasemnezhad, 2010; Soccol et al., 2010; Surawicz, 2010; Tiago et al., 2012; Zanello et al., 2009).

Nevertheless, for probiotic microorganisms to therapeutically exist effectively, it has been recommended that manufactured foods should contain a minimum of $10^7$ cfu/g probiotics and consumed no more than 100 g/day to contain useful consequences on the health state of the organism (Floch, 2014; Fuller, 1989; Gareau et al., 2010; Pourjafar et al., 2011; Soccol et al., 2010).

Saccharomyces cerevisiae var. boulardii (S. boulardii) is accurate probiotic yeast. The detection and budding of S. boulardii is firmly related to the impression of healthiness to promote microorganisms from foodstuffs. The most renowned and popularized foodstuff all over Europe for the hypothesis of healthiness to promote microorganisms is yogurt (Czerucka, et al., 2007; Heitman, 2006; Im and Pothoulakis, 2010; Lukaszewicz, 2012; McFarland and Bernasconi, 1993).

Henri Boulard who was in Indochina in 1920 throughout the cholera epidemic, detected that some inhabitants chewing the crust of lychee, and mangosteen or who prepare a particular tea did not experience the signs of the cholera disease. This inspection directed Boulard to the separation of a tropical strain of yeast named S. boulardii from lychee and mangosteen fruit, which is currently the only marketed probiotic yeast (Czerucka et al., 2007; Heitman, 2006; Lukaszewicz, 2012; McFarland and Bernasconi, 1993).

In the previous century, over half of the proposed probiotic prescription show that S. boulardii may be advantageous to the health of man. Boulard went back to France, where he separated and patented the strain and in 1947 sold it to Biocodex Company produced for its manufacture. S. boulardii was recorded as a medicine for the primary point in 1953 and until now it is the merely recorded eukaryotic probiotic microorganism (Czerucka, et al., 2007; Lukaszewicz, 2012).

This probiotic yeast was employed to be recognized as a split species as that of Saccharomyces cerevisiae, nevertheless, investigators have currently declared that S. boulardii is extremely like cerevisiae, consequently, it is a strain of cerevisiae. Conversely, the scientific name for it is Saccharomyces cerevisiae strain (or “variant” as it is sometimes identified) boulardii. However, S. boulardii is seen on the tags of manufactured goods (Büchl et al., 2010; Czerucka et al., 2007; Edwards-Ingram et al.,
S. boulardii is similar to S. cerevisiae in quality but lacks the capability to penetrate into tissues like Candida species, subsequently, they are not invasive (Buts and De Keyser, 2006; Buts and De Keyser, 2010; Calderone and Fonzi, 2001; Lukaszewicz, 2012; McFarland and Bernasconi, 1993; Whiteway and Oberholzer, 2004). S. boulardii is incapable of forming spores; hence the opportunities of its translocation to other parts of the body diminishes (Lukaszewicz, 2012; Zaouche et al., 2000). The most noticeable differentiation between these yeasts is the extraordinarily high growth of S. boulardii at a temperature of 37°C which fits excellently with the temperature of the human body. Also, the next significant aspect is its improved existence at acidic situation (Edwards-Ingram et al., 2007; Ferreira et al., 2010; Lukaszewicz, 2012). Several consequences of the survey on the differences and similarities between S. boulardii and S. cerevisiae are reviewed in Table 1.

Table 1. Outline of several dissimilarities and similarities between S. cerevisiae and S. boulardii (Lukaszewicz, 2012)

<table>
<thead>
<tr>
<th>Saccharomyces cerevisiae</th>
<th>Saccharomyces boulardii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower growth temperature (-30°C)</td>
<td>Higher growth temperature (-37°C)</td>
</tr>
<tr>
<td>Lower resistance to low pH</td>
<td>Higher resistance to low pH</td>
</tr>
<tr>
<td>utilize galactose</td>
<td>Do not utilize galactose</td>
</tr>
<tr>
<td>Sporogenous</td>
<td>Asporogenous on the contrary to S. cerevisiae but may produce fertile hybrids with of S. cerevisiae strains</td>
</tr>
<tr>
<td>There are steady strains with various ploidy</td>
<td>Trisomic for chromosome IX</td>
</tr>
<tr>
<td>Typing RFLPs or PCR failed to discriminate S. boulardii from S. cerevisiae</td>
<td>The Karyotype of S. boulardii are very like to those of S. cerevisiae</td>
</tr>
<tr>
<td>-</td>
<td>Microsatellite typing demonstrates genotypic variations</td>
</tr>
</tbody>
</table>

Yeast taxonomy is derived customarily from their biochemical and physiological sketches. Nevertheless, it fails to discriminate between a number of yeast species or cultivars and it causes an argument whether S. boulardii is used as a species or subspecies of S. cerevisiae. Consequently, other molecular techniques have been expanded and employed to yeast strain typing and recognition. In addition, metabolic tracking through mass spectrometry is possibly helpful in this regard. By means of gas chromatography time of flight in mass spectrometry, there is a superior association with this genetic technique of strain taxonomy. Probiotic strains of S. boulardii show a tense grouping which is both metabolic and genetic. The most important biased metabolites are: lactic acid, Capric acid, fumaric acid, trehalose, glycerol 3-phosphate and myoinositol (Buts et al., 1994; Büchl et al., 2010; Czerucka et al., 2007; Edwards-Ingram et al., 2004; Edwards-Ingram et al., 2007; Ferreira et al., 2010; Hennequin et al., 2001; Klis et al., 2006; Lukaszewicz, 2012; MacKenzie et al., 2008; Malgoire et al., 2004; Edwards-Ingram et al., 2007; Ferreira et al., 2010; Hennequin et al., 2001; Klis et al., 2006; Malgoire et al., 2005; McCusker et al., 1994; Mitterdorfer et al., 2002; Rajkowska et al., 2009).
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al., 2005; McCusker et al., 1994; Mitterdorfer et al., 2002; Murzyn et al., 2010b; Rajkowska et al., 2009).

Therapeutic functions of *S. boulardii*

A probiotic in terms of its advantageous outcomes, *S. boulardii* has various characteristics from the mainly fundamental to highly progressed. One of the major advantages of employing *S. boulardii*, particularly at the time of taking antibiotics, is that it is not influenced antibiotics because it contains yeast (Barc et al., 2008; Beaugerie and Petit, 2004; Can et al., 2006; Guslandi, 2010; Kotowska et al., 2005; McFarland, 2006; McFarland et al., 1995, McFarland et al., 1994; Szajewska and Mrukowicz, 2005). Consequently, it also assists to keep pathogenic microscopic organisms and yeasts for instance Candida, from overpowering the human body at the time the antibiotics demolish the majority of the useful bacteria and mainly, but not the entire bad bacteria in the human gastrointestinal lumen (Krasowska et al., 2009; Lukaszewicz, 2012; Whiteway and Oberholzer, 2004;). Some printed medicinal researches have shown the effectiveness and safety of *S. boulardii* for different illness indications in both adults and children (Guandalini, 2011; Im and Pothoulakis, 2010; Sougioultzis et al., 2006; Thomas et al., 2011; Zaouche et al., 2000), diarrhea in patients with enteral sensation (Centina-Sauri and Sierra Basto, 1994; Czerucka et al., 2007; Guandalini, 2011; Krasowska et al., 2010; Villarruel et al., 2007; Zanello et al., 2011), enhancement to hydration in adults and children (Kurugöl and Koturoğlu, 2005; Lukaszewicz, 2012; Szajewska and Skorka, 2009; Vandenplas et al., 2009), vaginal yeast infections (Heitman, 2006; Lukaszewicz, 2012; Skogaard, 2007), fever blisters (Lukaszewicz, 2012; Martins et al., 2011), canker sores and high cholesterol (Krasowska et al., 2007; Lukaszewicz, 2012; Czerucka et al., 2007). It has also been confirmed to be valuable in curing diarrhea related to the HIV virus (Lukaszewicz, 2012; Czerucka et al., 2007).

*S. boulardii* can stops intestinal diseases via the devotion *in vitro* or the attack *in vivo* of *E. coli*, *C. difficile* and *Candida albicans* to the gastrointestinal region. *In vitro* researches, show that *S. boulardii* diminishes the expansion of *E. coli*, *Salmonella typhimurium*, *Shigella*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *C. albicans*, *Entamoeba histolytica* and *Blastocystis hominis*. Also, *in vitro* studies...
illustrated that *S. boulardii* reduces cell invasion through *Yersinia enterocolitica* and *S. typhimurium* also showed *S. boulardii* damages, however it does not kill *H. pylori* (Castagliuolo et al., 1999; Chen et al., 2006; Cindoruk et al., 2007; Dahan et al., 2003; Dinleyici et al., 2011; Dinleyici et al., 2009; Fidan et al., 2009; Gedek, 1999; Krasowska et al., 2010; Lessard et al., 2009; Martins et al., 2010; Martins et al., 2011; McFarland, 2006; McFarland et al., 1994; Murzyn et al., 2010a; Murzyn et al., 2010b; Pontier-Bres et al., 2012; Rajkowska et al., 2012; Santino et al., 2014; Shareck and Belhumeur, 2011; Szajewska et al., 2010).

The prevalence of bacterial translocation in burn wound is increased through antibiotics, and this is decreased by *S. boulardii*, furthermore, it decreases the rate of antibiotic-stimulated bacterial translocation. *S. boulardii* contains an advantageous consequence in the cure of inflammatory bowel disease as restricted, *in vivo* (in mice), the number of immune cells that act in response to an inflamed colon. This restriction diminishes the strengthening of the inflammatory reaction, which results in less injury to the colon. It also helps to block the secretion of inflammation sourcing chemicals for the human body (Buts et al., 1990; Buts et al., 1986; Buts et al., 1994; Cain and Karpa, 2011; Chen et al., 2006; Dalmasso et al., 2006; Generoso et al., 2011; Lukaszewicz, 2012; Martins et al., 2005; Ng et al., 2011; Pothoulakis, 2009; Szajewaka and Mrukowicz, 2005; Zaouche et al., 2000).

*S. boulardii* stimulates the synthesis of various enzymes, for example the lactase enzyme employed to digest lactose, which enhances nutrient and electrolytic absorption. This yeast is able to stop feedbacks to foodstuff antigens in infants and young children that have "leaky gut" (Buts et al., 1994; Lukaszewicz, 2012; Murzyn et al., 2010b).

*S. boulardii*is generally taken in pill shape; however the dose differs depending on the required medication. In the cure of diarrhea with antibiotics, investigators generally prescribe daily doses in milligrams (mg) (Barc et al., 2008; Buts et al., 1986; Can et al., 2006; Krasowska et al., 2010; Lukaszewicz, 2012; McFarland, 2006; McFarland, 2010). Some recommendations for clinical application of *S. boulardii* in adults is summarized in Table 2.

<table>
<thead>
<tr>
<th>Employ pro disease</th>
<th>Employing dose (mg/ml)</th>
<th>Employing era</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cure of <em>Clostridium difficile</em> diseases</td>
<td>1000</td>
<td>28 days</td>
</tr>
<tr>
<td>Inflammatory bowel disease</td>
<td>750-1000</td>
<td>50 days to 180 days</td>
</tr>
<tr>
<td>Acute adult diarrhea</td>
<td>500-750</td>
<td>8-10 days</td>
</tr>
<tr>
<td><em>H. pylori</em> symptoms</td>
<td>1000</td>
<td>14 days</td>
</tr>
<tr>
<td>Irritable bowel syndrome</td>
<td>500</td>
<td>28 days</td>
</tr>
<tr>
<td>Enteral nutrition-related diarrhea</td>
<td>2000</td>
<td>8 - 28 days</td>
</tr>
<tr>
<td>Prevention of Travelers’ diarrhea</td>
<td>250-1000</td>
<td>throughout trip is 21 days</td>
</tr>
<tr>
<td>Prevention of antibiotic related diarrhea</td>
<td>500-1000</td>
<td>Throughout antibiotics with</td>
</tr>
<tr>
<td><em>Giardiasis</em></td>
<td>500</td>
<td>further 3 days to 14 days after</td>
</tr>
<tr>
<td>HIV-related diarrhea</td>
<td>3000</td>
<td>28 days</td>
</tr>
</tbody>
</table>

Table 2. Outline of recommendations for clinical employ of *S. boulardii* in adults (Lukaszewicz, 2012; McFarland, 2010)
Whereas it does not have side effects, ensure early supply of your medications before you start taking \textit{S.boulardii}, particularly if you are allergic to yeast, pregnant, or breast-feeding. \textit{S.boulardii} appears in over the counter supplements, which can be taken orally. To add further probiotic foodstuffs into our diet, there are extra alternatives other than just yoghurt (Büchlet \textit{et al.}, 2010; Czerucka and Rampal, 1999; Diezmann and Dietrich, 2009; Ferreira \textit{et al.}, 2010; Floch, 2014; Im and Pothoulakis, 2010). Cheese, butter milk, Kefir, kombucha, sauerkraut and miso, contain a wealth of digestive supporting probiotic microorganisms that are capable of normalizing the body (Floch, 2014; Fuller, 1989; Pourjafar \textit{et al.}, 2010; Vohra and Satyanarayana, 2012).

Generally, yeast as of Saccharomyces kind has been employed in humans and a better nourishment for all ages and innovative requests in industries are being expanded. These nourishments are of high quality and are utilized as food additive or to get several manufactured goods for instance the white or living cocktail (Buts \textit{et al.}, 1986; Büchlet \textit{et al.}, 2010; Czerucka \textit{et al.}, 2007; Vohra and Satyanarayana, 2012). Yeast cells are in addition a famous source of proteins, nucleic acids, vitamins and minerals, it contains a purely vigorous form of chromium, and identified as glucose tolerance factor (Czerucka \textit{et al.}, 2007; De Lianos \textit{et al.}, 2010; Lukaszewicz, 2012). \textit{S.boulardii} frees its passageway during gastrointestinal pathway at least with 1500 diverse compounds (Lukaszewicz, 2012; Martins \textit{et al.}, 2011; Zanello \textit{et al.}, 2011). At the same time as vitamins are compulsory exogenous natural compound which are also consumed, enzymes facilitate the change of bigger compounds to smaller ones which might be taken in by the brush rim. The brush rim is the structured shaped through which the micro villi raises the cellular surface region for emission, absorption, adhesion and transduction of indicators. Inside the gastrointestinal area, the brush rim is vital for digestion and nutrient absorption (Buts and De Keyser, 2010; Canonici \textit{et al.}, 2011; De Lianos \textit{et al.}, 2010; Toma \textit{et al.}, 2005; Zaouche \textit{et al.}, 2000). It has been demonstrated that oral administration of \textit{S.boulardii} improved the actions of the brush rim ectomembrane enzymes e.g. lactase, aminopeptidase and alkaline phosphatase. \textit{S.boulardii} cells have considerable quantities of polyamines (spermidine and spermine) which influences cell maturation, enzyme expression and membrane transport, consequently, polyamines were recommended as mediators in the intestinal trophic reaction (Buts \textit{et al.}, 1986; Buts \textit{et al.}, 1994; Büchl \textit{et al.}, 2010; Lukaszewicz, 2012).

Generally, in consumption time of products containing \textit{S.boulardii}; Side effects of dehydration and constipation are extraordinary and irrelevant in healthy individuals and takes just a few days. Diarrhea might take place when the flora of gastrointestinal lumen alters (Lukaszewicz, 2012).

\textbf{Conclusions}

\textit{S.boulardii} is a factual probiotic yeast superstar. There are plenty randomized, double-blind placebo-controlled investigations demonstrating the efficacy of \textit{S.boulardii} in the cure and prevention of gastrointestinal disorders (Choi \textit{et al.}, 2011; Kotowska \textit{et al.}, 2005; Maupas \textit{et al.}, 1983; McFarland \textit{et al.}, 1994; Szajewska and Skorka, 2009; Villarreal \textit{et al.}, 2007). For the past 30 years, doctors have suggested it to cure patients with diarrhea. It facilitates the adjustment of intestines and guards them from pathogens and other abnormalities in the gastrointestinal
lining. Doctors have also related the defects in the intestinal wall with diverse gastrointestinal illnesses. In contradiction to the majority of the indexed medicines which are distinct, pure composites, *S. boulardii* has been proven to be valuable through different mechanisms. Consequently, because of the diverse interactions of the compound, more studies should be conducted. However, it is furthermore very arduous, expensive and time consuming. There are a number of organisms in the conventional fermented foodstuff that has been investigated to be potentially advantageous for human well-being. Nevertheless, probiotic microorganism properties are strain explicit and extremely often not fine described. Properties of strains from the similar species might be extremely dissimilar; consequently for the well-being of humans, in addition, the advantages of the probiotic strain ought to be well illustrated. It is obvious that the micro flora of the human body is too complex and it is significant to maintain proper homeostasis, which can be disturbed by the intake of antibiotics. This can be averted or recovered by means of suitable probiotic microorganisms. Nevertheless, by reason of the complication of the probable interactions and diverse mechanisms of these actions, it is extremely complicated to record and commercialize probiotics. It is a big challenge to resolve this blockage in the future. These days, *S. boulardii* is regularly marketed as a probiotic in a lyophilized shape and is so often referred to as *S. boulardii lyo* (Lukaszewicz, 2012).

References


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