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Role of yeast cell wall polysaccharides in pig nutrition and health protection ☆

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Abstract

Polysaccharides are the major components of the yeast cell wall and play multiple functions, ranging from the carriers of immunochemical specificity and marker molecules, by which cells recognize each other and interact with the environment, to the skeletal substances that define stability, shape, and morphology of the cell. In *Saccharomyces cerevisiae*, the two major polysaccharides, constituting up to 90% of the cell wall dry weight, are α-D-mannan and β-D-glucan, which have remarkable properties to interact with the immune system of the host. Modulation of mucosal immunity by the binding of these two polysaccharides to the specific receptors of immune cells provides beneficial effects on animal health and resistance to diseases. Specific commercial yeast cell wall polysaccharides supplied in feed (Bio-Mos®, Alltech Inc.) are able to block fimbriae of pathogenic bacteria, and thus prevent their adhesion to the mucous epithelium. Since adhesion presents the first step in microbial invasion, blocking of the receptors may prevent or eliminate infection. Yeast cell wall polysaccharides are also able to adsorb mycotoxins, thus decreasing their toxic effect and mediating their removal from the organism. Commercial yeast polysaccharides (MTB100®, Alltech Inc.) have been shown to absorb a wide range of mycotoxins at low inclusion levels. Thus, especially if the ban on antibiotic growth promoters becomes global, use of yeast polysaccharides as natural growth stimulators becomes a very urgent and rewarding issue.

Keywords: Yeast cell wall; Polysaccharides; Mucosal immunity; Mycotoxins; Adhesion

1. Introduction

Almost 75% of the dry weight of the yeast cell wall is comprised of polysaccharides. The carcass of the yeast cell wall is built from the covalently linked complex of (1→3)-β-D-glucan, (1→6)-β-D-glucan, and chitin, while the amorphous component of the matrix as well as the fibrillar layer located on the yeast cell wall surface consists of mannoprotein. Fig. 1 represents a schematic slice of the yeast cell wall indicating the layers of individual polysaccharides. While β-D-glucans and chitin are responsible for rigidity of the cell wall and define its morphology and shape, mannoprotein and its carbohydrate portion – α-D-mannan – are responsible for cell–cell recognition and interactions, interactions with the environment, and determine immunological specificity of the yeast (Ruiz-Herrera, 1992). Interestingly, both types of the major polysaccharide constituents of the yeast cell wall – β-D-glucans and α-D-mannans – have

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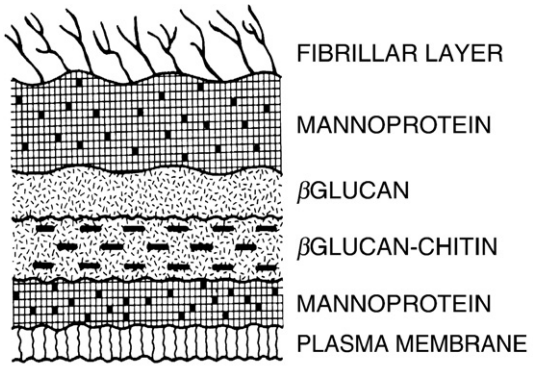

Fig. 1. Slice of the yeast cell wall showing the major polysaccharide components.

been recently recognized to be capable of pronounced modulation of the immune system of various living organisms from insects to humans through specific interactions with different immunocompetent cells (Medzhitov and Janeway, 2000). Since mucosal surfaces including gastro-intestinal, nasal, and broncho-alveolar organs represent the largest part of the animal body permanently exposed to the attack of pathogens and toxins, stimulation of the Common Mucosal Immune System (CMIS) represents a crucial task of animal health protection (Tlaskalová-Hogenová et al., 2002).

The ongoing debate on the use of antimicrobial growth promoters has intensified the search of alternative, especially natural bioactive materials capable of maintaining animal health and improving growth performance. The presented paper gives an overview of the positive results obtained at supplementing pigs with feed containing commercial yeast cell wall preparation Bio-Mos® at prevention of infectious diseases of various origins, as well as of the use of another yeast polysaccharide complex MTB100® (both Alltech, Inc., Nicholasville, KY) at elimination of the mycotoxins and inhibition of their toxic effect.

2. Immunomodulating activity of the yeast cell wall polysaccharides

β-D-Glucan, which constitutes 50–60% of total yeast cell wall polysaccharides belongs to the class of substances known as biological response modifiers (Bohn and BeMiller, 1995) and numerous studies have shown that (1→3)-β-D-glucans enhance the functional status of macrophages and neutrophils (Williams et al., 1996), modify immunosuppression (Browder et al., 1990), increase resistance to infections by Gram-negative bacteria (Pretus et al., 1991), as well as exert antitumor activity (Sherwood et al., 1986, 1987). In our previous work we have reported on antibacterial (Kogan et al., 1989), antimutagenic (Čipák et al., 2001), antioxidant (Babincová et al., 1999; Slameňová et al., 2003, Kogan et al., 2005), and antitumor activities (Kogan et al., 2002; Khalikova et al., 2005), as well as an ability to stimulate release of cytokines, such as TNF-α from macrophages (Majtán et al. 2005) of the prepared derivatives of (1→3)-β-D-glucan isolated from the cell walls of baker's yeast *Saccharomyces cerevisiae*.

Recently obtained data strongly support the assumption that (1→3)-β-D-glucans mediate their protective and immunopotentiating effect by binding to specific sites (receptors) on monocytes/macrophages and granulocytes triggering a cascade of immunological events (Brown 2006; Gantner et al. 2003; Herre et al. 2004; Willment et al., 2005). Among the elicited effects are: bone marrow colony stimulating activity leading to augmented production of monocytes and granulocytes, increased antibody titres, boosted cytokine release (including IL-1, IL-2, IL-6, and TNF-α), prostaglandin E_2 production, activation of alternative complement pathway, and release of lysosomal enzymes. It is now established that β-D-glucan receptors include CR3 (Ross et al., 1987), lactosylceramide (Zimmerman et al., 1998), scavenger receptors (Rice et al., 2002), and Dectin-1 (Brown and Gordon, 2001).

Another component of the yeast cell wall, α-D-mannan, also demonstrated antioxidant and antimutagenic activity (Križková et al., 2001), whereas a similar preparation from another industrial yeast strain, *Candida utilis*, revealed antimutagenic, antigenotoxic, and anticancer activity (Vlčková et al., 2004; Miadoková et al., 2006).

3. Mycotoxin-adsorbing activity of the yeast cell wall polysaccharides

Besides stimulating mucosal immunity at oral application and preventing oxidative stress due to their antioxidant and radical scavenging activity, yeast β-D-glucan was also shown to adsorb various mycotoxins (Šrobárová et al., 2005; Yiannikouris et al., 2004a,b) and therefore its admixture to the animal feed may lead to suppression of the toxic effect of these substances. Another yeast cell wall polysaccharide, α-D-mannan, suppressed toxic activity of mycotoxins probably by interacting with their toxic radical metabolites (Madrigal-Bujaidar, 2002).

4. Prevention of bacterial adhesion and dissemination by α-D-mannan

Mannose-specific lectins predominate in many intestinal bacterial pathogens and by binding to the

mannose-rich epithelial surface of gut and intestines they mediate adherence and subsequent colonization and infection (Baumler et al., 1997). α-D-Mannan binds to such mannose-specific lectin-type receptors (Type 1 fimbriae) of enteropathogenic bacteria such as *E. coli* and *Salmonella* spp. and in this way it serves as decoy and prevents adhesion to the mannose-rich surface glycoproteins of villi and subsequent colonization and dissemination of bacterial pathogens (Firon et al., 1983).

5. Health-promoting effect of commercial yeast cell wall preparations in pig nutrition

The two commercial preparations Bio-Mos® and MTB100® are produced from the yeast cell wall of *S. cerevisiae* by Alltech Inc. (Nicholasville, KY). Due to the content of the active polysaccharides β-D-glucan and α-D-mannan, application of these two products as feed supplement to pigs led to the beneficial results such as enhanced weanling piglets protection from bacterial infections and increased weight gain (Kim et al., 2000; LeMieux et al., 2003; Davis et al., 2002, 2004; Miguel et al., 2004; Rozeboom et al., 2005). In agreement with the established immunomodulating properties, administration of β-D-glucan led to enhanced T cell interferon-γ release in swine, which resulted in increased protection against porcine reproductive and respiratory syndrome virus (Xiao et al., 2004) and augmented resistance of pigs and newborn piglets against bacterial endotoxin (Eicher et al., 2006; Li et al., 2006), whereas α-D-mannan component played role in stimulation of the complement Mannan-Binding Lectin pathway, a crucial factor of protection due to innate immunity mechanisms (Dlabac and Kawasaki, 1994) and Bio-Mos® proved to be effective in weanling pigs against the infections caused by *Escherichia* and *Salmonella* spp. (White et al., 2002).

MTB100® showed improved mycotoxin-binding abilities in comparison with the traditional clay- or aluminium silicate-based adsorbents leading to the increased growth performance and health of starter pigs (Harvey 2000), improved fertility of sows fed with zearalenone-contaminated feed (Guerrero and Banegas, 2001; Frio et al., 2006), and suppressed detrimental effect of *Fusarium* mycotoxins on performance and metabolism of gestating sows (Díaz-Llano and Smith, 2005, 2006).

To test the bacterial lectin binding capacity of Bio-Mos®, we have performed agglutination tests using this preparation with 258 pathogenic strains of four bacterial genera. The strains were provided by the veterinarians from different countries all over the world and the agglutination tests were carried out according to Spring et al. (2000). The results of the agglutination are presented in Table 1. As can be seen, the tested product was efficient on average against 56% bacterial strains, while the highest activity was observed against the most wide-spread and dangerous pathogens *E. coli*, *S. enteritidis*, *S. typhimurium*, and *Clostridium* spp. Thus, *in vivo* health-protective and performance-improving activities of Bio-Mos® described in the cited articles, was fully corroborated by the performed *in vitro* tests. Recently, the agglutinating capacity towards various enteric pathogens was compared for Bio-Mos® and several other mannose-containing compounds (Newman, 2006) using the specifically designed aggregation rate coefficient (ARC) method. The results of ARC assay demonstrated superior efficacy of Bio-Mos® in binding and agglutination of bacteria.

Table 1
Agglutination of pathogenic bacteria by Bio-Mos®

Bacteria	Number of strains tested	Strains that agglutinate to Bio-Mos®	%
E. coli	143	92	64
Salmonella spp.	46	31	67
S. enteritidis	7	6	86
S. typhimurium	10	7	70
Clostridium spp.	5	4	80
Campylobacter spp.	7	1	14
Total	258	145	56

6. Conclusions

Taking into consideration all provided evidence on the beneficial action of yeast β-D-glucan and α-D-mannan on health and well-being of animals, it can be concluded that these polysaccharides and the products Bio-Mos® and MTB100® when applied as feed supplements render their beneficial action on pig health, growth and productivity by at least three mechanisms:

1. By inhibition of pathogen adhesion to GI epithelial tissue by blocking carbohydrate-binding adhesins on bacteria;
2. By stimulation of immunocompetent cells in Peyer's patches, large lymphatic tissues located in the mucous lining of small intestine and subsequent activation of innate and adaptive immune defense mechanisms. Boosting of mucosal immunity leads to general protection of animal health and productivity;
3. By adsorbing mycotoxins in feed and inhibiting their toxic action.

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