RESEARCH REPORT
ANIMAL SCIENCE

Title: Aspects of yeast-based products in enhancing animal production – **NPB #05-134**

Investigator: Christopher D. Mateo, DVM, PhD

Institution: Rural Technologies, Inc., 1008 32nd Avenue, Brookings, SD 57006

Date Submitted: October 1, 2006

Abstract: A literature review on yeast and yeast-based products as potential alternative feed additives to enhance animal production was conducted. This review includes a description of the yeast compound and specific components relevant to yeast product processing. The process of drying yeast, controlling the growth environment of yeast, and yeast cell fractionation is discussed, and products from these procedures such as active dried yeast, yeast-based mineral products, yeast culture, yeast glucan, yeast mannanoligosaccharide, yeast glucomannan, and yeast nucleotides were taken into account. Considerations in developing a challenge model for assessing yeast-based product efficacy were reviewed, and a listing of challenge models currently utilized for this purpose is provided. Market analysis of the different yeast-based products was performed, and a database of yeast-based products marketed locally is presented. In addition, an electronic patent intelligence search on data from the yeast-based product market analysis was accomplished, and patents and patent applications that claim any elements relating to yeast-based products, existing patents relating to yeast-based products, and patent applications that describe similar elements of patented inventions conflicting with the results presented were compiled. This manuscript may serve as a valuable reference material for swine producers interested in understanding the potential role of yeast and yeast-based products in enhancing swine production and as a starting point for basic and applied swine research studies. Understanding and determining possible options to further process an existing yeast product or develop other potential yeast-based products will allow swine nutritionists to better position these products and optimize their use in the feed industry.

Aspects of Yeast-based Products in Enhancing Animal Production

BY

C. D. Mateo[*1], J. Schwartz[1], J. Knoblock[2], J. Clarke[3], A. Klein[1], N. Runke[1], D. Waldner[1], and C. S. Mark[1]

[1]Rural Technologies, Inc., Brookings, SD
[2]Enterprise Institute, Brookings, SD
[3]Independent Inventor Institute, Brookings, SD

October 1, 2006

[*] Principal Investigator

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AA	Amino acid
ACTH	Adrenocorticotrophic hormone
ADFI	Average daily feed intake
ADG	Average daily gain
AGP	Antibiotic growth promoter
AID	Apparent ileal digestibility coefficient
Arg	Arginine
AST	Aspartate aminotransferase
Ca	Calcium
cfu	Colony forming units
Con A	Concanavalin A
CP	Crude protein
Cr	Chromium
Cr-Pic	Chromium picolinate
Cu	Copper
CVM	Center for Veterinary Medicine
DDGS	Distillers dried grains with solubles
DM	Dry matter

DRS	Direct repeat sequences
DTH	Delayed-type hypersensitivity
EE	Ether extract
EGM	Esterified glucomannan
EU	European Union
FDA	Food and Drug Administration
Fe	Iron
FOS	Fructooligosaccharide
GE	Gross energy
G:F	Gain:feed
GI	Glycemic index
GlcNAc	N-acetylglucosamine
GOS	Galactooligosaccharide
GRAS	Generally recognized as safe
GTF	Glucose tolerance factor
HSCAS	Hydrated sodium calcium aluminosilicate
IFNγ	Interferon gamma
IgA	Immunoglobulin A
IgG	Immunoglobulin G
IgM	Immunoglobulin M

IL	Interleukin
IL-1Ra	IL-1 receptor antagonist
IMO	Isomaltooligosaccharide
KLH	Keyhole limpet hemocyanin
LPS	Lipopolysaccharide
MOS	Mannanoligosaccharide
MW	Molecular weight
Na	Sodium
nm	Nanometer
P	Phosphorous
PC	Phosphatidylcholine
PE	Phosphatidylethanolamine
Phe	Phenylalanine
PI	Phosphatidylinositol
ppb	Parts per billion
ppm	Parts per million
PRRS	Porcine reproductive and respiratory syndrome
PS	Phosphatidylserine
RNA	Ribonucleic acid
S. cerevisiae	*Saccharomyces cerevisiae*

SDPP	Spray dried plasma protein
Se	Selenium
SID	Standardized ileal digestibility coefficient
T_3	Triiodothyronine
Th1	Type 1 helper T-lymphocyte
TLR-2	Toll-like receptor-2
TNFα	Tumor necrosis factor alpha
Trp	Tryptophan
Val	Valine
VFA	Volatile fatty acids
Vit.	Vitamin
WHO	World Health Organization
Zn	Zinc

LIST OF TABLES

LIST OF FIGURES

1. Introduction

The global issue of antibiotic resistance in humans has been a concern for the past two decades. During this time, consumer demand for organic food products has increased dramatically. Consequently, a ban on specific antibiotic growth promoters (AGP) in swine diets was introduced in Sweden, Denmark, and in all European Union (EU) countries in 1986, 1998, and 1999, respectively. While the removal of AGP in growing-finishing pig diets did not cause an increase in the therapeutic use of antibiotics in growing and finishing pigs, a reduction in pig performance and an increase in weanling pig disease were observed when AGP was taken out of nursery pig diets. To address this concern, changes in management, feeding strategies, and diet modifications were implemented to manage the decrease in pig performance and compensate for the removal of AGP in swine diets.

To date, no single feed additive or management practice can enhance animal growth cost-effectively in weanling pigs compared to administering AGP. This has prompted animal scientists and swine nutritionists to investigate possible cost-effective alternatives to the use of antibiotics in animal feed. Alternative feed additives such as dietary acidifiers, enzymes and enzyme-mixtures, essential oils, herbs, immune stimulator products, plant extracts, prebiotics, and probiotics have been introduced as potential replacements for antibiotics. A prospective alternative to antibiotics that is currently being evaluated is yeast and its derivative products. To accurately establish the value of yeast and yeast-based products as alternative feed additives to enhance swine production, it is necessary to conduct an extensive and critical review of literature on this feedstuff.

2. Compound description

Yeasts are classified as unicellular fungi. Although similarities exist, the presence of organelles distinguishes yeasts from prokaryotes. Yeast and prokaryotes are both aerobic and anaerobic organisms and reproduce by sexual and asexual means. Scientific advances utilizing yeast have been monumental. In 1861, Louis Pasteur proved that yeast was a living organism (Barnett, 2000). One hundred thirty-five years later, completion of the *Saccharomyces cerevisiae* genome was announced on April 14, 1996 (N. H. G. R. Institute, 1996). The three main types of yeast that are commonly used to produce feed and food grade yeast-based products are *Phaffia rhodozyma*, *Candida utilis*, and *Saccharomyces cerevisiae* (Figure 1). By far, the most studied type of yeast is the last. Whereas a number of yeast-based products available on the market utilize whole yeast as base material, new generation products have been derived from specific yeast cell components such as the cell wall, the cell membrane, and the cell extract.

Yeast cell wall. Investigation of the yeast cell wall reveals a dynamic organelle that plays an intimate role in the regulation, transport, defense, and life cycle of yeast. The yeast cell wall is the principal structure that differentiates the yeast cell from animal cells and comprises 15-25% of the total dry mass of the cell. The thickness of the yeast cell wall is generally 100-200 nm. It has two layers, an inner and outer leaflet, and is found outside of the plasma membrane. While the principal role of the inner layer is maintaining the strength and integrity of the cell wall, the outer layer is in contact with the environment of the cell and is responsible for maintaining cell shape, modulating transport, and monitoring environmental conditions.

Polysaccharides make up 80-90% of the yeast cell wall and consist of glucans and mannans. A minor component of the yeast cell wall is chitin, a linear polymer of N-acetylglucosamine (GlcNAc) residues joined by β-1-4-linkages. While glucans and mannans are major components of the cell wall, chitin accounts for only 1-2% of its dry weight.

Yeast plasma membrane. The plasma membrane in yeast is a lipid bilayer that is approximately 7.5 nm wide. It plays a key role in numerous cellular processes including transport of molecules, signal transduction, and anchoring of the cytoskeleton. It is separated from the cell wall by a periplasmic space. Significant differences in lipid composition of the inner and outer bilayer exist. While phosphatidylcholine (PC) and sphingolipids make up the majority of lipids in the outer layer, phosphatidylethanolamine (PE), phosphatidylinositol (PI), and phosphatidylserine (PS) are predominantly found in the inner layer. The yeast plasma membrane contains mainly ergosterol and minute amounts of zymosterol while completely lacking cholesterol. Ergosterol found in yeast can be converted to Vitamin D_2 by irradiation, and the resulting product from this process is called irradiated yeast. Cows fed irradiated yeast produce milk that is rich in Vitamin D.

Yeast cell extracts. The portion of yeast cells remaining after cell wall removal is referred to as yeast cell extract. Batch-grown bakers yeast is the most common source of yeast extract. Yeast cell extract is a good source of yeast-based AA, biopeptides, nucleotides, enzymes, water soluble vitamins, and minerals used in a variety of markets and applications. However, large commercial utilization of yeast extracts can be limiting due to the added preparation expense over autosylates.

3. Yeast processing

There are numerous yeast-based products available on the market today that are products of different base material processing methods. The majority of yeast compounds described in this paper are products of either a specific type of drying, fractionation process, or a controlled growth environment.

3.1 *Drying*

The process of drying yeast is an industry in itself. Machines utilizing a variety of methods are available, but all processes involve concentrating yeast through the removal of water. Further drying, shaping, and packaging procedures lead to the production of different industrially important yeast products (Figure 1). Descriptions of common dried yeast products are provided (Table 1).

3.1.1 *Active dried yeast*

Active dried yeast is a live yeast product that has been dried in order to preserve its fermenting activity and contains fewer than 15×10^9 live yeast cells per gram (AAFCO, 2005). Active dried yeast (or live yeast) differs from yeast culture in that the media in which the yeast is grown has been removed. As a result, active dried yeast products contain a greater concentration of viable yeast cells than yeast culture products. In general, an increased growth performance due to greater nutrient availability (Jurgens et al., 1997) and improved gastrointestinal health due to inhibition of pathogenic organisms are the main benefits of active dried yeast supplementation in animal feed.

Several mechanisms of action have been proposed for live yeast products such as toxin inhibition (Castagliuolo et al., 1999), antagonistic interactions with pathogens in the intestine (Ducluzeau and Bensaada, 1982), stimulation of brush border disaccharidases (Buts et al., 1994), phytase activity (Vohra and Satyanarayana, 2001), adsorption of mannose-specific pathogens to yeast cell wall mannans, and immunomodulation by yeast cell wall glucans. All these mechanisms have been the basis for responses observed with dietary active dried yeast supplementation and are largely similar to that of dietary yeast culture supplementation.

The interaction between *Saccharomyces cerevisiae* var. *boulardii* (referred to as *S. boulardii*) and *Candida albicans* was observed (Ducluzeau and Bensaada, 1982). The researchers found that continuous administration of *S. boulardii* to gnotobiotic mice in order to maintain a steady population of 10^9 cells caused *C. albicans* to become established at a rate of 10 to 50 times lower compared to the control group. *In vivo* characterization of this antagonism was also found to be effective against *C. albicans, C. krusei*, and *C. pseudotropicalis* but not against *C. tropicalis*. However, this antagonistic effect was not observed when *S. boulardii* was heat killed.

The inhibitory effects of live yeast such as *S. boulardii* on toxins of intestinal pathogens such as *Salmonella typhimurium* and *Shigella flexneri* (Rodrigues et al.,1996) and *Clostridium difficile* toxins A and B (Castaglioulo et al., 1999; Qamar et al., 2001) have been demonstrated. In these studies, mice fed diets supplemented with *S. boulardii* had a higher immunoglobulin concentration compared to the control animals. It has been reported that weanling rats fed diets supplemented with lyophilized *S. boulardii* resulted in an increase in intestinal sucrase and maltase activity by 157% and 47%, respectively (Buts et al., 1994). The researchers suggested that the up-regulation of these intestinal enzymes were due to an increase in polyamine concentration (i.e., spermidine and spermine) found in ileal and jejunal fluid from rats fed diets supplemented with lyophilized *S. boulardii* compared to the control group. Because decreased activities of intestinal disaccharidases are associated with some diarrheas, live yeast supplementation in animals may potentially increase resistance to diarrheal diseases in addition to its inhibitory effects on intestinal toxins (Auclair, 2001).

While there were no differences observed in feed intake, litter size at birth, litter birth weight, or litter weight at 21 days post-farrowing, sows fed diets supplemented with active dried yeast produced milk that contained a higher concentration of total solids, CP, and IgG compared to the control group (Jurgens et al., 1997). Moreover, an analysis of two parities suggest that weaned piglets fed diets supplemented with active dried yeast from dams also fed diets supplemented with active dried yeast had improved ADG and feed efficiency compared to the control pigs. Similarly, it has been shown that dietary supplementation of active dried yeast improved growing pig performance (Huegten et al., 2003). Although active dried yeast supplementation did not appear to have the potential to replace the effects of antibiotic inclusion in the diet, it did have a synergistic effect.

3.2 *Controlled growth environment*

Controlling the growth environment of yeast is arguably the most important factor in achieving consistent products during industrial utilization. The source, rate, and timing of nutrient addition into the growth environment are all factors that influence yeast

metabolites, growth phase, and products of yeast processing. This is particularly true for yeast-based mineral products (Figure 2).

3.2.1 *Chromium yeast*

The World Health Organization (WHO) conducted a study reviewed by Hunt and Stoeker (1996) that suggested chromium (Cr) is an essential nutrient (Mordenti et al., 1997). Although Cr may have advantages, the toxicity related to its use plays a major role in its acceptance worldwide. While many European and non-European countries allow Cr supplementation in animal diets, the use of Cr has been banned in other countries of the European Union (Mordenti et al., 1997). The U.S. Food and Drug Administration's (FDA) Center of Veterinary Medicine (CVM) permits the inclusion of up to 200 ppm Cr picolinate (Cr-Pic) in swine diets (Shields, 1997). Toxicity and utilization of this mineral are form-specific. Chromium exists in different chemical forms that may be divided into two major groups, organic and inorganic. Of the inorganic forms of Cr, only Cr III (Cr^{3+}) is biologically active and considered nontoxic. The therapeutic: toxic dose ratio of Cr^{3+} is 1:10,000, indicating that Cr is safe in this form (Mowat, 1997). While Cr IV is toxic, this form is converted to Cr^{3+} in the digestive tract (Wenk, 1995). Similarly, hexavalent Cr (Cr^{6+}) is reduced inside cells to Cr^{3+}. Hexavalent Cr is irritating, carcinogenic, antigenic, and corrosive when absorbed in intestinal, pulmonary, and skin tissues (Mordenti et al., 1997). Nutrient availability of dietary Cr is dependent on the type, source, and processing method of this mineral (Mordenti et al., 1997). It has been shown that Cr^{3+} absorption ranges from 0.4 to 3.0% or less, which is independent of dose and dietary Cr status of the animal (Anderson et al., 1983). Because of the low bioavailability of inorganic Cr, organic forms of Cr were considered. It has been reported that the bioavailability of organic forms of Cr is between 25 to 30% (Mowat, 1997). Available forms of organic Cr that have been studied and documented in literature include Cr-Pic, Cr nicotinate, and Cr yeast. By far, the most studied form of organic Cr is Cr-Pic.

The role of Cr as the active ingredient of the glucose tolerance factor (GTF) has been well established (Schwartz and Mertz, 1957). As a function of the GTF, Cr increases glucose uptake and improves insulin efficiency (Mordenti et al., 1997). This is a result of a membrane phosphotyrosine phosphatase activation from a low molecular weight Cr-binding protein released in conjunction with the insulin response after a meal (Davis et al., 1996). The ability of exogenous insulin to increase the frequency of luteinizing hormone pulses that consequently increases ovulation rate has been reported (Britt et al., 1988). Chromium supplementation in sow diets increases tissue sensitivity to insulin, which may serve as a signal within the sow to resume estrous and result in an improvement in litter size (Lindemann et al., 1995).

While it has been reported that supplemental Cr-Pic increases serum growth hormone concentrations, findings have been inconsistent (Page et al., 1993). The utilization of Cr appears to be species-specific with notable responses during advancing age, periods of reproduction, stress, and dietary deficiencies (Lindemann, 1996). Stressed steers fed diets supplemented with Cr yeast had a linear decrease in serum cortisol as Cr supplementation increased and tended to have higher IgG_1 blood concentration compared to the control group (Moonsie-Shageer and Mowat, 1993). Stressed calves fed diets supplemented with Cr yeast showed an increase in DMI, ADG, and feed efficiency compared to the control group (Chang and Mowat, 1992). Whereas these results suggest

that Cr supplementation may be beneficial during periods of stress in calves, this may not be true in other species. While no effect on piglet growth and neutrophil superoxide production was observed, blood concentration of nonesterified fatty acids was higher and glucose concentration was lower at 7 days post-weaning in pigs fed diets supplemented with Cr yeast compared to the control group (Baldi et al., 1999). In addition, although insulin and cortisol concentration were unaffected, blood glucose concentration decreased in weanling pigs challenged with ACTH and fed diets supplemented with Cr yeast compared to the control group. As a result of improved glucose utilization, the authors concluded that Cr yeast supplementation may not affect the stress response unless extreme conditions are present.

Growing pigs fed diets supplemented with Cr have improved ADFI, ADG, and feed efficiency (Page et al., 1993; Amoikon et al., 1995; Lindemann et al., 1995; Van Heugten and Spears, 1997; Kornegay et al., 1997). It has been reported that pigs fed diets with a low glycemic index (GI) had decreased growth performance, and pigs fed diets with a high GI had an increase in carcass fat deposition (Lemme et al., 2000). The authors concluded that GI may influence chemical composition of the longissimus muscle and efficacy of dietary Cr. Another study showed that Cr chloride, Cr yeast, and Cr-Pic supplementation at 0.5 ppm in barley- and wheat-based diets did not affect performance during the growing period; however, both growth rate and feed conversion efficiency were improved during the finishing period (Wenk et al., 1995). While the carcass composition scores were better with Cr yeast and Cr-Pic supplementation, the differences were not significant. The authors suggested that Cr yeast supplementation did not affect back fat thickness but increased muscle surface area. Chromium is also thought to play a role in gene expression, and it has been debated whether Cr affects nuclear protein and ribonucleic acid (RNA) synthesis to the point of altering carcass traits, or if the changes result from differences in growth hormone levels. It has been shown that Cr binds to the chromatin and enhances RNA synthesis by causing an increase in the number of initiation sites, which result in an increase in muscle protein available for the building of muscle tissue (Okada et al., 1989). Because of the role of Cr in enhancing insulin activity, supplementation may positively affect carcass traits by reducing back fat while increasing longissimus muscle area and percent muscling.

3.2.2 *Selenium yeast*

Early studies first recognized the protective effect of selenium (Se) against necrotic liver degeneration in rats and identified Se as an essential nutrient (Schwartz and Foltz, 1957). Scientists later discovered the protective effect of Se against oxidative damage due to its role as a component of the enzyme glutathione peroxidase (Rotruck et al., 1973). Further research into the biological roles of Se eventually led to FDA approval of inorganic Se as a feed additive (FDA, 1974). Current regulations allow a dietary Se inclusion rate of up to 0.3 ppm for chickens, swine, turkeys, sheep, cattle, and ducks (FDA, 1987). Despite the fact that many feed companies commonly add Se into most swine diets at this level in the form of Na selenite or Na selenate, Se deficiency continues to be a concern (Mahan, 2004).

It has been reported that thoroughbred horses fed diets supplemented with Na selenite had higher levels of excreted fecal Se compared to horses fed diets supplemented with Se yeast (Pagan et al., 1999). In ruminants, inorganic Se can be utilized as an

electron acceptor by microorganisms in the rumen and is reduced to insoluble forms that interfere with Se absorption in these animals (Kincaid et al., 1999). While inorganic Se crosses the intestinal epithelia via passive diffusion, methionine and selenomethionine are actively transported, allowing for greater absorption (Edens and Gowdy, 2004). The use of yeast as a Se source provides this mineral in the form of selenium-containing AA. More specifically, Se is substituted for the sulfur component in methionine, cystine, and cysteine to become selenomethionine, selenocystine, and selenocysteine, respectively (Mahan, 1999). This indicates that the apparent absorption of organic Se is greater than the inorganic form. Recently, the use of Se yeast as an alternative to the conventional inorganic forms of Se has been approved (FDA, 2002).

Research studies on Se yeast supplementation have been conducted in cattle (Hemken et al., 1998), sheep (Kincaid et al., 1999), broiler chickens (Edens, 2001), catfish (Lovell and Wang, 1997), horses (Pagan et al., 1999), and pigs (Mahan and Peters, 2004). The findings from Se yeast supplementation research include greater digestibility and retention of organic Se (Pagan et al., 1999), increased transplacental and transmammary Se concentration (Mahan, 2004), increased sow fertility, increased litter size, fewer still births (Mahan, 2004), and increased T_3 thyroid hormone concentration (Edens and Gowdy, 2004).

Sows fed diets supplemented with or without 0.3 ppm of Na selenite over a four-parity period had decreasing milk Se concentration with each subsequent parity (Mahan and Peters, 2004). However, when sows were fed diets supplemented with 0.3 ppm Se yeast, the drop in Se concentration in milk from one parity to the next was not observed. In addition, the Se concentration in milk was higher in sows fed diets supplemented with Se yeast compared to sows fed diets supplemented with or without 0.3 ppm Na selenite. Similarly, a higher concentration of Se in milk at day ten of lactation was reported in sows fed diets supplemented with Se yeast compared to sows fed diets supplemented with Na selenite (Gourley et al., 2005). While researchers reported that the increase in Se concentration in the milk led to an increase in piglet Se serum concentration, increased litter weight at weaning, and total litter gain during lactation when the sows were fed diets supplemented with yeast extract, no differences in ADG, ADFI, or feed efficiency were observed in weanling pigs fed diets supplemented with either Na selenite or Se yeast. It has been shown that sows fed diets supplemented with Se yeast tended to have higher serum Se concentrations at farrowing and higher colostral and milk Se concentrations compared to the concentrations seen in sows fed diets supplemented with Na selenite (Yoon and McMillan, 2006). In addition, piglets whose dams were fed diets supplemented with Se yeast had higher serum Se concentrations than those piglets whose dams were fed the control diet. While these findings support the work conducted by Mahan and Kim (1996) for milk Se concentration, the authors reported that colostral Se concentration was unaffected by the source or level of Se.

An increase in the number of stillbirths was observed when sows were fed diets supplemented with either 0.15 or 0.30 ppm of Na selenite compared to sows fed diets supplemented with Se yeast (Mahan and Peters, 2004). Although the researchers reported fewer neonates with evidence of splay-legged condition when sows were fed Se yeast, the results were not significant. In addition, while mortality in piglets from sows fed diets supplemented with Se yeast was lower compared to piglets from sows fed diets supplemented with Na selenite, the Se source in the piglet diet had no effect on mortality.

This finding suggests that piglet growth and survivability are increased when the sow is fed a diet supplemented with organic Se. In another study, Se was added at either 0.1 or 0.3 ppm with either Na selenite or Se yeast to a corn-soybean meal diet to evaluate gilt reproductive performance. The results showed that although the concentration of gilt serum glutathione peroxidase activity and loin tissue Se concentration were similar in stillborn and neonatal pigs, the Se concentration in loin tissues increased as inclusion level increased when the gilts were fed diets containing Se yeast (Mahan and Kim, 1996). While both Se yeast and Na selenite inclusion reduced the number of stillbirths per litter compared to the basal control group, serum Se concentration, serum IgG concentration, and glutathione peroxidase activity in piglets did not differ between treatment groups at 14 days of age (Yoon and McMillan, 2006).

A total of 0, 0.05, 0.1, 0.2, or 0.3 mg Se/kg in the form of either Se yeast or Na selenite was added to a grower/finisher diet containing 0.06 mg Se/kg (Mahan et al., 1999). The authors showed that while no differences in performance or carcass quality as a result of Se source were observed, serum Se concentration and glutathione peroxidase activity increased as Se inclusion increased. Although it has been reported that grower/finisher pigs fed diets supplemented with Na selenite showed an increase in drip loss and a linear increase in paleness of loin meat as a result of additional Se inclusion in the diet, these results where not observed with pigs fed diets supplemented with Se yeast (Mahan et al., 1999). In addition, an increasing Se tissue concentration was observed as dietary Se levels increased, but the increase was higher for pigs fed diets supplemented with Se yeast. It was suggested that the inclusion of Se yeast in finisher pig diets may enhance antioxidant activity, and thus improve cell membrane integrity and reduce drip loss in pork (Torrent, 1996). In contrast, the use of inorganic Se can have a pro-oxidative effect that may oxidize lipids and reduce the integrity of cell membranes in muscle tissues (Edens and Gowdy, 2004).

3.3 *Yeast cell fractionation*

The three methods most commonly utilized in yeast cell fractionation are autolysis, enzymatic lysis, and physical disruption of the cells (Figure 3). Although all three methods are utilized in producing feed grade yeast-based products, autolysis or self-digestion is used specifically in the wine and brewing industries to give a specific flavor to the product. Physical disruption uses glass beads to crack open the cell and is commonly used in basic research involving yeast. Similarly, enzymatic lysis is labor-intensive with multiple steps required to obtain the desired product. The interior of the cell contains a rich source of nutrients including nucleotides, vitamins, minerals, proteins, and AA. Protocols for isolating these specific nutrients and components are available. For instance, subfractionation techniques can be used to purify specific components. Depending upon which fraction of yeast is used, a wide range of applications is possible.

3.3.1 *Yeast cultures*

Yeast culture is defined as a mixture containing yeast cells (usually *S. cerevisiae)* and the culture medium in which they are grown. This mixture is dried in a certain way to prevent the destruction of its nutrient content (Lynch and Martin, 2002). While most studies conducted on yeast culture supplementation have been in ruminants, including dairy goats and beef and dairy cattle (Salama et al., 2002; Lynch and Martin, 2002), and

poultry (Bradley and Savage, 1995), studies have also been conducted in monogastric animals such as horses (Hill et al., 2001) and swine (Huegten et al., 2003). The findings reported in dietary yeast culture supplementation studies include an increase in ADFI due to increased palatability (Wallace, 1996), increased milk production in dairy animals (Alshaikh et al., 2002), increased nutrient availability for beneficial microflora (Wallace, 1996), stimulation of lactate-utilizing bacteria and cellulolysis in the rumen (Callaway and Martin, 1997), and decreased diarrhea due to *Clostridium difficile*-associated colitis (Elmer and McFarland, 1987; Castagliuolo et al., 1999).

Investigating the exact mechanism of action of yeast culture products is a challenge due to the complexity of yeast culture and the differences between cultures (Wallace, 1996). Due to the presence of cell wall-associated molecules such as mannan and glucan, the adsorption of yeast cell wall mannan to mannose-specific lectins on bacteria expressing Type 1 fimbriae and the stimulation of macrophages by glucan would also be expected for yeast culture supplements.

A study was conducted to compare *in vitro* ruminal fermentation between yeast culture and live yeast (Lynch and Martin, 2002). Although the yeast culture contained 1.16×10^4 cfu/g and the live yeast contained 1.39×10^7 cfu/g, both supplements had similar effects on ruminal fermentation. Interestingly, when both yeast supplements were diluted to 1:10 in deionized water, the concentration of malate, glucose, and lactate detected was elevated for both yeast culture yeast and live yeast. These carbon sources in the supplements may have contributed to the observed increases in concentrations of fermentation products such as methane and VFA such as acetate, propionate, and butyrate. In contrast, a reduction in the ratio of acetate to propionate was also observed. For dairy animals, a reduced acetate to propionate ratio is believed to be associated with milk fat depression (Sutton et al., 2003).

Autoclaving yeast cell culture products negatively impacts stimulatory activity (El Hassan et al., 1993); conversely, when yeast culture products are irradiated, many of the stimulatory effects are retained. While metabolic capabilities of yeast remain largely intact after irradiation, yeast is unable to reproduce. These findings suggest that either metabolic functions or heat-labile components of yeast are responsible for the effects of yeast culture in ruminants.

Another proposed mechanism of action for the effects of yeast culture involves the ability of yeast to uptake oxygen in the rumen (Wallace, 1996). This would promote the activity of strict anaerobes and improve feed digestibility. The ability of metabolically active-irradiated yeast and inability of autoclaved yeast to stimulate bacteria in the rumen would support this hypothesis. It has been reported that oxygen uptake by yeast is dependent on VFA concentrations (Lee et al., 2003). The normal total ruminal VFA concentrations (between 86.6 and 92.8 mM and between 100.7 and 107.5 mM, reported by Sutton et al., 2003, and Broderick et al., 2002, respectively) are too high for *S. cerevisiae* to be able to uptake oxygen (Lee et al., 2003). Although differences between strains were reported, oxygen uptake by yeast likely does not explain the effect of yeast culture.

Hamsters that were fed *S. boulardii* had lower concentrations of *C. difficile* after challenge compared to the control group (Elmer and McFarland, 1987). The researchers reported the apparent absence of *C. difficile* toxins in samples from hamsters given the yeast culture. Similar results have been shown to decrease diarrhea in humans with

recurrent *C. difficile*-associated colitis when *S. boulardii* was given along with vancomycin or metronidazole treatments (Castagliuolo et al., 1999). In addition, the authors reported that a 54-kDa serine protease secreted by *S. boulardii* was capable of *in vitro* degradation of both A and B toxins of *C. difficile*. Supplementing *S. boulardii* cultures in broilers and turkey poult diets has resulted in increased weight gain and improved feed conversion ratios (Newman, 1995).

While dietary yeast culture supplementation studies in swine have been conducted, interactions with feed, differences in inclusion rates, variations in yeast culture metabolic activity rates, and yeast strain differences have led to variable results. Although a higher ADG and ADFI was observed in weanling pigs fed pelleted diets supplemented with live *S. cerevisiae* culture, only a higher ADFI accompanied with a lower G:F was reported in weanlings fed nonpelleted diets supplemented with live *S. cerevisiae* culture compared to the control group (Mathew et al., 1998). In addition, there were no differences observed for intestinal microbial count (i.e., total lactobacilli, total streptococci, total *E. coli*, and total yeast) and fermentation product concentration (i.e., acetate, propionate, butyrate, valerate, isovalerate, and isobutyrate) in pigs fed diets supplemented with live *S. cerevisiae* compared to the control group. Piglets from sows fed diets supplemented with yeast culture (*S. cerevisiae*) had higher birth and weaning weight compared to the control group (Murray and Dawe, 1996). Moreover, the researchers reported that feeding yeast added to a corn- and soybean meal-based diet to sows improved CP digestibility and increased total lipid concentration in sow milk. In contrast, no effect was observed on sows and their litters in terms of nutrient digestibility and reproductive performance when yeast culture was added to gestation and lactation sow diets (Reyes et al., 1991; Veum et al., 1995). It has been reported that sows had reduced weight loss during lactation when fed lactation diets supplemented with yeast culture (Reyes et al., 1991). Conversely, pig performance was unaffected by yeast culture supplementation in grower pig diets (Murray, 1994; Kornegay et al., 1994:1995). Although phytase activity is present in yeast culture, studies have failed to produce positive results in improving phosphorus utilization in swine (Kornegay et al., 1995).

3.3.2 *Yeast glucans*

Glucans are glucose polymers commonly found as cell wall components of plants, fungi, and bacteria (Williams, 1997), but rarely found in animals (Kataoka et al., 2002). Glucans are often secreted into the environment by glucan-producing microorganisms and are minor constituents of fungal cytosol (Williams, 1997), most abundantly in the β-linked form (Ruiz-Herrera, 1991). Plant-derived β-glucans that largely consist of β-1,3 chains with β-1,4 branching have received much attention for their cholesterol-lowering activities (Plat and Mensink, 2005) and are believed to be the active hypocholesterolemic component in oats (Beer et al., 1995).

It has been demonstrated that these fungal β-glucans, which consist mostly of a (1,3)-β-D-glucopyranosyl chain with branches consisting of (1,6)-linked single units of β-D-glucopyranosyl, have the potential to stimulate an immune response (Williams, 1997; Hiss and Sauerwein, 2003). Macrophage hyperplasia and hyperfunctionality are believed to be the main reasons for this enhanced response (Kokoshis et al., 1978; Chen and Ainsworth, 1992). In addition, β-glucans are thought to trigger the alternative pathway for complement activation (Hamuro et al., 1978), enhance the production of reactive

oxygen species (Plat and Mensink, 2005), increase serum lysozyme concentrations (Kokoshis et al., 1978), increase serum antibody titers following immunization (Chen and Ainsworth, 1992), and activate Th1 differentiation through the production of IL-12 by activated macrophages (Brown and Gordon, 2003; Plat and Mensink, 2005). A small receptor (28,000 MW), dectin-1, was identified that was able to recognize β-1,3-linked and β-1,6-linked glucans from plants and fungi (Brown and Gordon, 2001). Co-stimulation of TLR-2 and dectin-1 has been shown to be required for the production of IL-12 and TNF-α via the transcription factor NF-κB in response to zymosan (Brown et al., 2003). The researchers reported that dectin-1 mediates the proinflammatory response against live cells of *S. cerevisiae* and *C. albicans*. Clearly, the recognition of yeast cell wall β-glucan by dectin-1 serves an important role in the response to fungal parasites by the innate immune system.

It has been observed that channel catfish fed diets supplemented with *S. cerevisiae*-derived glucan had elevated phagocytic indices and macrophage bactericidal activities (Chen and Ainsworth, 1992). Moreover, elevated levels of TNF-α, IL-1β, IL-6, IL-8, and IL-12 by glucan-activated macrophages were observed (Brown and Gordon, 2003; Plat and Mensink, 2005). In contrast, it has been reported that particulate β-glucan (i.e., Zymocel) preferentially enhances IL-1Ra production *in vitro* (Poutsiaka et al., 1993). Furthermore, the authors reported that IL-1 production is not stimulated unless large concentrations of β-glucan (i.e., >100 μg/ml) are supplemented. IL-1Ra is a competitive inhibitor of IL-1 and can down-regulate the pro-inflammatory response to IL-1. Because IL-1 has been implicated in septic shock, rheumatoid arthritis, and leukemia, the researchers concluded that β-glucan may provide some protection to these diseases due to its stimulation of IL-1Ra production.

A study suggested that *Escherichia coli*-challenged turkeys fed diets supplemented with yeast-derived β-glucan had an increase in growth performance compared to turkeys in the control group (Huff et al., 2002). Although the yeast-derived β-glucan had a notable effect on the profile of peripheral blood leukocytes, no differences in mortality were observed between the treated and control groups after challenge. It was also concluded that larger doses of β-glucan had detrimental effects on both growth performance and mortality.

An increase in ADG and ADFI was observed in weanling pigs fed diets supplemented with 0.025% β-glucan compared to pigs fed diets supplemented with either 0.1% or 0.05% β-glucan (Dritz et al., 1995). In contrast, there was a 50% and 20% mortality rate in pigs fed diets supplemented with 0.025% and 0.05% β-glucan, respectively, 10 days post-infection with *Streptococcus suis*. The authors suggested that hygiene status of the animals may impact the effect of dietary β-glucan supplementation (Dritz et al., 1995; Hiss and Sauerwein, 2003). This conclusion was supported when a growth response was detected in pigs fed diets supplemented with β-glucan and housed in farms with poor hygiene status compared to pigs in a farm with low immune stimulation (Decuypere et al., 1998). In another study, weanling pigs were fed diets supplemented with 0.02% β-glucan without or with antibiotics. The results showed that although an increase in CD4 and T lymphocytes was observed in pigs fed β-glucan alone, the researchers concluded that pigs fed diets supplemented with antibiotics showed better

nutrient digestibility and ADG than pigs fed diets supplemented with β-glucan (Hahn et al., 2006).

No significant differences in ADG and feed efficiency were found in weanling pigs fed diets supplemented with either 0.015% or 0.03% β-glucan compared to pigs feed a control diet (Hiss and Sauerwein, 2003). In contrast, ADFI was increased in pigs fed diets supplemented with 0.03% β-glucan compared to pigs in the control group. Moreover, the researchers reported that there were no differences in antibody titers in pigs fed diets supplemented with either 0.03% or 0.015% β-glucan following vaccination against PRRS. While it was suggested that no correlation exists between ADFI and G:F to *S. cerevisiae*-derived β-glucan supplementation in an initial study, the authors reported an increase in ADG of weanling pigs fed diets supplemented with 50 ppm of β-glucan for the first 28 days and ADFI during the entire duration of a subsequent 35-day experiment (Li et al., 2006). These findings were similar to those described by Hahn et al. (2006) when the authors reported a linear increase in ADG of weanling pigs fed diets supplemented with increasing amounts of β-glucan. In addition, DM, GE, CP, EE, Ca, and P digestibility also increased linearly with increasing β-glucan supplementation. No differences were observed in ADG, G:F, and meat characteristics in grower/finisher pigs fed isonitrogenous and isocaloric oat diets supplemented with natural plant-based β-glucan compared to pigs fed the control diet (Fortin et al., 2003). However, the authors reported an increase in soluble protein as β-glucan inclusion increased, as well as lower commercial loin from pigs fed diets containing either 3.3% or 4.1% β-glucan when compared with the control animals.

Although a decrease was reported in lymphocyte proliferation index response to Con A and phytohemagglutinin after day 14 of β-glucan supplementation in pigs, the authors showed an increase in IL-6 serum concentrations at 1.5, 3, and 4.5 hours post-challenge to LPS in barrows fed diets supplemented with 50 ppm β-glucan for 28 days prior to challenge in a succeeding study (Li et al., 2006). In addition, similar results were obtained for TNF-α at 3 and 4.5 hours and IL-10 at 3, 4.5, and 6 hours compared to barrows challenged with saline. These findings support the work conducted by Mao et al. (2005) when the authors reported that IL-2 bioactivity and lymphocyte proliferation responses to Con A increased linearly with increasing β-glucan supplementation.

While no effect on ADG and G:F was observed in weanling pigs fed diets supplemented with plant-derived β-glucans (included at 0, 500, or 1,000 mg/kg) when challenged with LPS, weanling pigs fed diets supplemented with 500 mg/kg of β-glucan had a higher ADFI compare to pigs in the other treatment groups (Mao et al., 2005). Moreover, pigs fed diets supplemented with β-glucan had a decreased production of the proinflammatory cytokine IL-1β, as well as prostaglandin E2, compared with challenged pigs not fed β-glucan.

Although structural diversity of glucans has resulted in many inconsistencies in experimental data that may be due to differences in molecular weight, degree of branching, tertiary structure (Brown and Gordon, 2003), and dose (Dritz et al., 1995; Huff et al., 2002), β-glucans may offer possibilities for immune modulation in animals.

3.3.3 *Yeast mannanoligosaccharides*

Mannanoligosaccharides (MOS) are complex carbohydrates found in the outer cell wall of fungi (*S. cerevisiae*) and are commonly utilized as a feed additive (possible

alternative to AGP) in animal diets (Ferket et al., 2002; Hooge, 2004). It has been reported that the immunomodulatory effect of MOS varies according to the strain and growth conditions of the yeast strain used (O'Carra, 1998). The effect of MOS on gastrointestinal health and growth performance has been evaluated in poultry (Hooge, 2004), horses (Ott, 2005), dogs (O'Carra, 1998), fish (Staykov et al., 2005), and pigs (Miguel et al., 2002).

Adsorption of pathogenic intestinal microflora (Spring, 1995; Kocher and Tucker, 2005), increased numbers of goblet cells per millimeter of villus height, increased villus height to crypt depth ratio in the jejunum (Hooge, 2004; Kocher and Tucker, 2005), increased IL-2 and IFN-γ production, and increased phagocytic activity (Spring and Privulescu, 1998) have all been reported benefits of MOS. Two mouse monoclonal antibodies specific for cell wall mannan were produced from *C. albicans*. One of these monoclonal antibodies was found to be protective against candidal adhesion and subsequent infection, which suggests that mannans play an integral part in the pathogenesis of parasitic yeast (Han and Cutler, 1995). While other oligosaccharides such as GOS, FOS, and IMO can serve as substrates to beneficial microflora in the gut such as bifidobacteria and lactobacilli, MOS is relatively unaltered by intestinal bacteria (Spring, 1995). In addition, the digestive enzymes of the gastrointestinal tract are incapable of hydrolyzing the linkages found in these oligosaccharides (Spring, 1995).

Many pathogens possess mannose-specific lectins on their surfaces that are compatible to mannose residues on the surface glycoproteins of enterocytes. These lectins allow for attachment and colonization of the intestinal wall, which is a prerequisite for many enteric disease infections. Therefore, the ability of bacterial lectins to bind to MOS and thereby inhibit intestinal wall attachment is the proposed mechanism of action in enhancing gastrointestinal health (Ferket et al., 2002). *In vitro* agglutination of *Salmonella montevideo, S. give, S. kedougou, S. dublin,* five of seven strains of *E. coli*, and seven strains of *S. enteritidis* and *S. typhimurium* when treated with MOS was observed; however, no agglutination was noted for *S. pullorum* and *S. choleraesuis,* and no or weak agglutination for *Campylobacter jejuni* and *C. coli* was established (Spring et al., 2000).

It was demonstrated that sows fed diets supplemented with MOS have an increase in ADG and fewer days post-weaning return to estrus (Funderburke, 2002). Piglets from sows fed diets supplemented with MOS have decreased pre-weaning mortality, increased average birth weight, and increased average weaning weight. The author added that MOS has the ability to bind mycotoxins, thus making them unabsorbable. MOS supplementation in sow diets increases colostral IgA, IgG, and IgM concentrations (Funderburke, 2002). This increase in colostral immunoglobulin concentration was also observed in mare milk when mares were fed diets supplemented with MOS (Ott, 2005). In addition, foals from mares fed diets supplemented with MOS experienced no diarrhea severe enough for treatment compared to foals in the control group. Similarly, positive effects on piglet diarrhea have been reported in weanling pigs fed diets supplemented with MOS due to the adsorption of potentially toxigenic bacteria in the digestive tract (Spring and Privulescu, 1998).

A number of studies have been conducted to evaluate the use of MOS in combination with antibiotics and microminerals. It has been suggested that the inclusion of MOS along with antibiotics may replace the inclusion of excess Zn in weanling pig

diets (LeMieux et al., 2003). In another study involving three farms, the inclusion of tylosin and sulfamethazine with or without MOS increased both ADG and ADFI. While the inclusion of MOS also increased ADG and G:F in one of the farms, performance differed among farms in this study (Rozeboom et al., 2005). Although an increase in ADG and ADFI was observed in weanling pigs fed diets supplemented with MOS, the addition of MOS to finisher diets containing added Cu resulted in a decrease in ADG of finisher pigs (Davis et al., 2002). Thus, the performance of finisher pigs fed diets supplemented with MOS may be dependent on the inclusion level of Cu in the diet.

It has been reported that the inclusion of brewers dried yeast (*S. cerevisiae*) as a source of MOS in experimental weanling pig diets decreased ADFI, which resulted in lower ADG (White et al., 2002). Although there was no significant increase in lactobacilli count, the inclusion of MOS in piglet diets tended to reduce fecal coliform count (White et al, 2002). A meta-analysis of growth performance in nursery pigs fed diets supplemented with MOS was conducted (Miguel et al., 2002). The analysis included 49 performance comparisons of pigs fed diets supplemented with MOS at 0.01% to 0.04% of the diet. It was suggested that the inclusion of MOS significantly increased ADG, ADFI, and feed efficiency based on mean percent differences from the controls. The authors concluded that an inclusion rate of 0.02% MOS in the diet at an early weaning age and during the first two weeks post-weaning appeared to have the most substantial effect on growth performance. Similarly, a meta-analysis of growth performance in broiler birds fed diets supplemented with MOS was conducted (Hooge, 2004). In 35 out of 44 comparisons, both feed efficiency and average final weight were increased due to dietary MOS supplementation. Interestingly, dietary MOS supplementation had a beneficial impact on mortality compared to the antibiotic-treatment group. These results suggest that MOS may be a potential alternative to antibiotics in monogastric animal diets.

3.3.4 *Yeast glucomannans*

Mycotoxins are products produced from fungal metabolism that can be problematic when consumed by livestock, particularly swine (Smith et al., 2004). These fungi can grow on various grains and forages in the field or in storage (Ledoux and Rottinghaus, 1999) and may potentially end up in animal feedstuffs. If present in high concentrations, mycotoxins have a wide array of detrimental effects on animal productivity and reproduction (Dawson et al., 2001). Due to the adverse effects of mycotoxins, different methods of control have been explored. These strategies can be broken down into two categories involving either changes in feed management or nutritional manipulation. Of these two approaches, nutritional manipulation has emerged as the most practical and cost-effective (Dawson et al., 2001). Nutritional approaches to controlling mycotoxins include feed additives such as antioxidants to control tissue damage (Lin et al., 1994; Atroshi et al., 1995; Grosse et al., 1997; Ibeh and Saxena, 1998); phenolic compounds for detoxification (Aboobaker et al., 1994); chemoprotectants like aspartame (Baudrimont et al., 1997), piperine (Reen et al., 1997), coumarin (Goeger et al., 1998); chlorophyll derivatives (Dashwood et al., 1998); and serotonin antagonists (Prelusky et al., 1997).

Other nutritional methods focus on a product's ability to adsorb or "bind" mycotoxins. These additives may be either inorganic or biological in nature. While

inorganic clay-based adsorbents and activated charcoals including HSCAS, zeolites, and bentonites have all been used because of their inert nutritional status (Piva et al., 1995), these products have limited efficacy against multiple toxins and require high inclusion levels (Devagowda et al., 1998). Some inorganic adsorbents may also reduce the biological value of certain nutrients and contain harmful dioxin and heavy metals (Yiannikouris et al., 2005). The use of a primary biological adsorbent found within the carbohydrate complexes of the cell wall of the *S. cerevisiae* yeast organism may eliminate the drawbacks seen in inorganic adsorbents (Dawson et al., 2001). Esterified glucomannan (EGM) extracted from the cell wall of yeast has a strong affinity for certain mycotoxins without inhibiting mineral metabolism like activated charcoal does (Murphy, 2002) by trapping mycotoxins within the holes in its texture. The material in the yeast cell wall varies in adsorption ability depending on the mycotoxin (Dawson et al., 2001). It has been reported that EGM adsorbs a wide range of mycotoxins (Bruerton, 2001) and suggested that it is possible to chemically modify the yeast cell wall to create mycotoxin-specific adsorbents (Dawson et al., 2001).

Glucomannans alleviate the negative effects of mycotoxins by binding to them, allowing the toxins to pass through the digestive tract without being absorbed. Glucomannans have the capacity to bind up to 60-65% of mycotoxins consumed when added to the diet at a lower inclusion rate compared to inorganic adsorbents; however, binding ability is dependent on the specific type(s) and level(s) of mycotoxins present (Whitlow et al., 2006). An *in vitro* study showed that up to 88% of aflatoxin was neutralized (either by degradation or adsorption of the toxin) when a *S. cerevisiae* culture was added to a fungal culture broth (Devegowda et al., 1994). The authors added that aflatoxin neutralization was dependent on incubation time and the level of *S. cerevisiae* culture added. It was suggested that the molecular structure and resulting bond formation occur between different mycotoxins and the β-D-glucan fraction of the yeast cell wall (Yiannikouris et al., 2005).

While swine is regarded as the most sensitive species to mycotoxins in the feed with respect to feed refusal and reproductive failure (Smith et al., 2004), research in the area of mycotoxins has focused primarily on *in vitro* experiments and *in vivo* studies involving poultry. Trials conducted using broiler chickens, laying hens, and turkeys indicated that addition of EGM to diets contaminated with mycotoxins reversed the negative effects of the toxins (Smith et al., 2004).

In swine, weanling pigs fed diets containing 80 ppb aflatoxin and supplemented with EGM at 0.2% of the diet performed better than pigs fed diets containing aflatoxin without EGM supplementation. The increase in performance was attributed to greater aflatoxin adsorption ability from the addition of EGM in the diet (Khajarern and Khajarern, unpublished data). In contrast, no effect on ADFI and G:F was observed in starter pigs fed diets naturally contaminated with Fusarium mycotoxins and supplemented with EGM; however, the addition of EGM at 0.2% of the diet reversed the depression of norepinephrine, 3,4-dihydroxyphenylacetic acid, and dopamine in the pons (Swamy et al., 2002). This finding suggests that while EGM did not affect performance, it may influence specific neurochemical signals. The addition of EGM to grower/finisher diets improved ADG, average muscle mass, carcass output, and certain qualities of meat such as boiling loss, water coherence, and meat rigidity in pork (Junka and Shimkus, 2002).

In vitro and *in vivo* experiments suggest that EGM is effective in binding mycotoxins present in feedstuffs. However, alleviation of mycotoxin-related symptoms in swine remains a necessary area of study.

3.3.5 *Yeast nucleotides*

Nucleotides are ubiquitous molecules with considerable structural diversity. They are composed of a nitrogenous base linked to a sugar to which at least one phosphate group is attached. A chain of nucleotides attached together via a phosphodiester linkage at the 3' and 5' positions of neighboring ribose units are called polynucleotides or nucleic acids (Voet and Voet, 1995). It has been reported that the concentration of 5'monophosphate nucleotides change during the initial week post-partum, but during the last two weeks of a four-week sow lactation period, the concentration is constant (Mateo et al., 2004).

The study of nucleotides and nucleic acids has been of interest because of the many functions attributed to them. Evidence suggests that nucleotides are important because of their participation in physiological reactions that are essential to the maintenance and propagation of life. The need for nucleotides is elevated during periods of rapid growth, stress, and in immunocompromised animals (Carver and Walker, 1995). In newly weaned pigs, all of these factors are present; therefore, it is expected that the pigs have a high requirement for nucleotides during the immediate post-weaning period. Because nucleotide synthesis is an energy- and glutamine-requiring process and because newly weaned pigs are often deficient in both energy and glutamine, it is possible that pigs are not able to synthesize sufficient quantities of nucleotides during this period.

Pigs fed diets supplemented with yeast extract as a source of nucleotides performed similarly with the pigs fed diets with SDPP in terms of ADG, ADFI or feed efficiency during phase-1 and -2 post-weaning (D. C. Mahan, unpublished data). In a study conducted to determine the AID and SID coefficients of AA and CP in yeast extract and SDPP by weanling pigs using the difference method, the results indicated that the AID for CP and all AA with the exception of cysteine and serine are similar between yeast extract and SDPP (Mateo, 2005). In addition, no differences in SID for AA or CP were observed between yeast extract and SDPP. The researcher added that yeast extract and SDPP contain protein that is relatively well digested by young pigs.

Feeding nucleotide-rich yeast extract protein improved gut health and growth rate of weanling pigs, and provided long-term improvement in growth rate of growing and finishing pigs comparable to the feeding of SDPP (Carlson et al., 2001). Nucleoside and nucleotide supplementation during the immediate post-weaning period positively influences the gastrointestinal microflora by decreasing enterobacteria and increasing *L. acidophilus* and Bifidobacterium species. In addition, nucleotide and nucleoside supplementation increases ileal villous height and villous height: lamina propria depth thus improves gastrointestinal morphology and consequently nutrient absorption (Mateo, 2005).

It has been found that a mixture of nucleotides similar to those in human milk exerts a protective effect in the intestinal lumen of piglets against an inflammatory response to ischemia-reperfusion (Bustamante et al., 1994). However, the protective effects seen in the intestinal lumen were not due to nucleotides alone. Synthetic β-carotene and nucleotide addition increased lymphocyte stimulation to

phytohaemagglutinin and Con-A in weanling piglets by 50% and 30%, respectively (Zomborsky-Kovacs et al., 1998). Piglets fed yeast RNA for two to four weeks improved lymphocyte function as evidenced by their increased T-cell-mediated DTH responses to KLH and *in vitro* proliferative responses to a non-specific T-cell mitogen (Cameron et al., 2001). Pigs with *E. coli* infection fed diets supplemented with yeast extract as a source of nucleotides at 4% (Maribo, 2003) and 2.5% (P. Spring, unpublished data) improved weight gain, reduced diarrhea, and improved feed conversion compared to pigs fed the control diet. After stress induced by transport and slaughter, growing pigs fed a nucleotide mixture (2.1%) during the last 30 days of fattening had lower serum creatine kinase, lactate dehydrogenase, and AST concentrations compared to animals fed a standard diet (M. Zomborsky, unpublished data). These results suggest that the need for nucleotides is elevated during periods of stress and in immunocompromised animals.

4. Challenge model development

The first record of an animal model used for research was by Galen of Pergamam (A.D. 130-200), a physician of the Roman emperor (Gallin, 2002). Since that time, animal models have been voluminous in literature and contributed significantly to the progression of science. An animal model is defined as a laboratory animal that applies or relates structured information to an area of interest (Melby, 1987). An experiment that is conducted in an animal is termed *in vivo*. In contrast, an experiment that is performed in cells extracted from an animal (i.e., tissue culture) is termed *in vitro*. Both types of experimental procedures have advantages and disadvantages. The expense of acquiring and housing experimental animals and training personnel for *in vivo* studies is high compared to *in vitro* studies. In addition, the complexity of determining the correct structure of the model is complicated due to vast confounding cellular events within the animal. Profundity of federal, state, and local governmental laws and formalities of animal welfare can also be overwhelming. Contamination risks associated with experimental animals can have profound consequences on project funding and completion. Injury and liability of personnel who handle the animals are also an issue. Although animal research models may have disadvantages, these models have been widely accepted to demonstrate analogous meaning for an area of interest. A number of animal challenge models have been used in yeast-based product supplementation studies to determine their effect on specific parameters (Table 2).

While Cr and Se yeast products provide an alternative and more bioavailable mineral source, other yeast-based products have been positioned in the feed industry as potential alternatives to antibiotics and AGPs in response to an increase in antibiotic resistance. Efficacy of these yeast-based antibiotic and AGP alternatives has been evaluated primarily in young animals. It is at this stage of life in which animals are more prone to stress such as environmental, gastrointestinal, and dietary changes. Most challenge model studies using weanling pigs involve stress induction (i.e., environmental stress, ischemia reperfusion, transport, etc.) and microbial, aflatoxin, specific mitogen, and other potential pathogenic challenge material. By far, the most widely used measures of efficacy in these studies have been immunological profile in blood, microbial and enzyme concentration, specific stress indicators, and performance. However, the balance between modulating the immune system and improving animal production parameters warrants more investigation. Understanding the exact mechanism of action of these yeast-

based products in disease prevention and treatment is key in developing an effective challenge model. Because of the differences in the mechanism of action of these yeast-based products, the use of different challenge models for different products should be considered. While comparisons and conclusions made among research studies involving yeast-based products are confounded by product purification method, source, and inclusion rate, ascertaining challenge model specificity and sensitivity would positively correlate with results that count.

5. Existence of branded products

A compilation of yeast-based products marketed locally is provided (Tables 4-9). Market analysis of the different yeast-based products was conducted using the Internet. Keywords and phrases used in the Internet search process are indicated in Table 3. Product composition, description, dosage, and packaging are included. Moreover, the manufacturers, distributors, and suppliers are listed for easy reference. While this yeast-based product database is relevant to animal nutritionists, livestock raisers, feed manufacturers, feed additives manufacturers, and students, it must be noted that the database should not be taken as a guarantee that other, similar products do not exist. The indications and benefit claim summaries for each yeast product category were based on individual product labels and brochures reviewed. The information presented will be useful in increasing livestock productivity and enhancing production efficiency.

5.1 *Active dried yeast*

A number of yeast products that fall into the active dry yeast category that are used in animal feed were identified. These products are separated into three classes, namely: tunnel dried yeast, fluid bed dried yeast, and rotolouver dried yeast. The bulk of the products originate from a leading yeast-feed company, the Lesaffre Group (Milwaukee, WI). The Lesaffre Group is a French-based company that maintains a library of over 1,000 pure culture yeast strains. Smaller companies including Saf Agri and Red Star Yeast fall under its organization. The other major yeast manufacturers identified are Lallemand Animal Nutrition (Milwaukee, WI) and its subsidiary, American Yeast Corporation (Baltimore, MD), and Cypress Systems, Inc. (Fresno, CA).

Indications. Yeast has been used as a nutritional feed supplement for many animal feed products. It is used in livestock and poultry feeds primarily as a source of protein. Tunnel dried yeast in particular has been used in most animal feeds and is especially useful for swine, poultry, and milk replacers for young ruminant diets. Benefits include a reduction in pathogenic bacteria and digestive disorders associated with weaning and starting diets and improved ADFI, ADG, FCR.

5.2 *Yeast cultures*

A number of unique yeast culture products that several companies have developed specifically for use in the livestock industry have been identified. While most of these companies market their yeast culture products as feed additives, Medipharm Cultures (Des Moines, IA) sells its product in pre-dosed syringes. By far, the two most common yeast genus derivatives that compose the bulk of these cultures are *Saccharomyces cerevisiae* and Bacillus spp.

Indications. Yeast cultures are used in feed for a wide variety of animal industries, including dairy, swine, beef, horse, poultry, aquaculture, and pets. These products may be used with feed premixes, base mixes, and complete feed or as a feed top dress. An improvement in feed consumption in piglets fed starter diets supplemented with yeast cultures has been suggested. Supplementation of these products in grower/finisher diets improves feed digestion by stimulating the normal microflora, reduces cannibalism and manure volumes, and aids in manure odor control. Producers frequently comment on the products' ability to reduce incidence of ulcers as well. Because there is no market feed withdrawal concern with this product, supplementation of yeast cultures in grower/finisher diets may decrease days to market and have better public acceptance of the pork product. Yeast cultures increase the animals' ability to digest fiber and improve feed utilization. Yeast cultures produce erqusterol, sterols, lipids, glycolipids, and some polypeptides. During fermentation, these cultures also produce acetate, which is the precursor of fat synthesis. Yeast cultures have been added into swine diets to speed transition to full feed, improve feed utilization, eliminate constipation, and increase milk production in lactating sows. Pigs fed diets supplemented with these cultures have been shown to have quicker responses to antibiotic treatments and dewormers, improved bone development in younger animals especially, reduced death loss and disease, improved feed conversions and rates of gain.

5.3 *Nutritional yeast*

While we have identified different nutritional yeast products, only brewers dried yeast is relatively common in the feed industry today. Primary dried yeast is not cost-effective for animal feed and is used almost exclusively in the pet food industry. Whey yeast is no longer marketed in the feed industry; however, a few products still exist. Torula dried yeast products for the feed industry have not been identified. Torula yeast is primarily marketed for food products and occasionally is added to pet food products to improve palatability. Phaffia yeast is a new product being used in the aquaculture industry.

Indications. Primary dried yeast was designed for use in animal feed, pet food, and as a medium for certain types of research. It has outstanding palatability characteristics and is an excellent source of protein and B-vitamins. This product has several functional properties that assist with extruded product processing, improve appearance of baked products, and allow additional water inclusion. It is the preferred medium for propagation of fruit flies (Drosophila) used in genetic research. Brewers dried yeast has been used in the diets of beef and dairy cows, poultry, broilers, layers, turkeys, sheep, goats, pets, pigs and horses. Brewers dried yeast supplementation optimizes animal health and performance, prevents pathologies due to stress, favors the development of lactic ferments, and increases immune defenses that reduce the possibility of gastrointestinal tract infection. In piglets and sows, brewers dried yeast favors bioregulation of intestinal bacterial flora, effectively stimulates digestive metabolism, and improves pig performance. Whey yeast was designed to increase performance and feed utilization for animals under the stress of showing, breeding, lactation, and growth. Phaffia yeast is an economical alternative to feeding an expensive crustacean diet, and a "natural" alternative to the chemically synthesized astaxanthin pigment currently used in the aquaculture industry, as well as in other applications such

as pigmentation of shrimp, poultry, and egg yolk. It provides equal or better pigmentation in salmon and trout compared to synthetic pigments and is used primarily as a source of pigment in fish feed for salmonids.

5.4 *Yeast-based mineral products*

Our findings were classified into the following categories, namely: selenium (Se) yeast, chromium (Cr) yeast, iron (Fe) yeast, and zinc (Zn) yeast.

Indications. Se yeast is an essential micronutrient for dairy and beef cattle, chickens, turkeys, horses, sheep, goats, and swine. Organic Se in the form of Se yeast is at least 50% more bioavailable than inorganic Se such as Na selenite and is designed to provide a more digestible source of the mineral. Organic Se as selenomethionine may be incorporated into body proteins such as muscle tissue, whereas inorganic Se cannot be. Cr yeast is a useable and available source of Cr and included in dairy and beef cattle, swine, and horse diets. Cr yeast has been suggested to increase lean percentage and muscle growth rate and decrease fat and serum cholesterol levels in swine. Organic Cr supplementation in animal diets has been reported to decrease cortisol levels in stressed animals. Supplementation of organic Cr maximizes animal production through eliminating Cr deficiency problems (i.e., reduced growth rate and increased mortality and morbidity). Advantages of Cr yeast over inorganic Cr sources are related to bioavailability, improved regulation of carbohydrate metabolism, reproduction, and meat quality. Fe and Zn yeasts are designed to provide a more digestible source of their inorganic mineral counterparts in livestock feeds and pet foods.

5.5 *Yeast fractions*

Product categories that were identified are as follows: yeast cell walls, yeast β-glucans, yeast mannan, yeast glucomannan, yeast autolysates, yeast extracts, and yeast nucleotides.

Indications. Yeast cell walls are primarily composed of mannan and β-glucans and are supplemented in animal diets to increase resistance against disease and improve growth and feed conversion. Supplementation of yeast cell walls activates phagocytosis and bactericidal activity. Yeast cell wall products bind to pathogenic bacteria and inhibit intestinal villi colonization in the gut. Pigs fed diets supplemented with yeast cell walls and reared under conditions of low stress and minimal pathogen challenge have improved growth and feed efficiency. This product provides a profound benefit when fed to pathogen-challenged pigs or pigs under stress conditions and may also serve as nutrition for a few beneficial bacteria in the gut that aid in pigs' growth and reproduction. Yeast cell wall supplementation in shrimp diets has been used to prolong lifespan by preventing the blaze, vibrio, and other diseases of shrimp. Yeast cell wall products may be formulated for optimal dispersion into either compound feed or premixes and are compatible with most conventional feed ingredients or feed additives used in feed manufacturing. Specific yeast cell wall components are used as immunostimulants that promote monocycte, neutrophil, fibroblast, collagen and elastin production, as well as macrophage activation that upregulates IL-1. The activation of macrophages in turn stimulates the production of IL-2, which fuels the immune system. Other applications of yeast cell wall components include: vaccine adjuvants, fat replacers, cholesterol

reduction, wound healing, cosmetic skin repair, and thickeners for foods and feed supplements.

Yeast mannan products are biological gut microfloral modifiers and natural prebiotics included in swine starter diets to enhance digestion, feed intake, and performance. Yeast mannan products may be formulated with other milk products and provide a highly digestible source of lactose and protein to maximize feed intake and growth. Other yeast mannan-based products may contain quality animal protein and highly digestible sources of AA that improve gain and feed efficiency.

Yeast glucomannan products are commonly used in animal diets as natural mycotoxin binders and palatability enhancers that stimulate feed intake.

Yeast autolysates may be formulated to insure optimal flow within the industrial process and homogenous repartitioning into feed premixes. This product is compatible with most feed ingredients and additives commonly used in feedstuff manufacturing. Yeast autolysates are routinely used in the food industry as flavor enhancers or pure flavors, aroma enhancers, and may serve as coloring agents. Increasing areas of interest for yeast autolysates are pathostatic applications, oncological preparations, and cancer therapy.

Yeast extract has been recommended in diets of young animals with digestive or immune problems and is a good source for dietary nucleotides supplementation.

Yeast β-glucanase products are natural enzyme blends that are used as a concentrated source of hydrolytic enzymes for dairy, livestock, pet, pork, and poultry applications.

5.6 *Other related yeast-based products*

A market analysis on functional carbohydrate yeast-based products [i.e., mannanoligosaccharides (MOS), fructooligosaccharides (FOS), a-galactooligosaccharides (GOS), and transgalactooligosaccharides (TOS)] was conducted. Several MOS and FOS products were identified. In contrast, no GOS or TOS products were found. Although two products that are oligosaccharides used in swine feed were identified, they do not fall under the MOS, GOS, FOS, or TOS product category. Other products included in this section are products either having yeast as an ingredient or using yeast as a base material prior to processing (e.g. enzymes).

Indications. In general, MOS is an all-natural GRAS product with no withdrawal period. MOS provides an effective and safe alternative to antibiotics. In addition, MOS helps control the proliferation of vibrios, improve overall performance of young animals, retard pathogen colonization, reduce the incidence of scours in cattle and pigs, promote the growth of beneficial lactic acid-producing bacteria, improve feed conversion, and stimulate immune responses at the cellular and humoral levels.

FOS is a natural prebiotic that stimulates the growth of beneficial intestinal bacteria that support a healthy colon condition. This relationship has a positive effect on digestive system function, as well as the overall health of the animal. Dietary FOS supplementation promotes a healthy gut microflora rich in Lactobacillus and Bifidobacteria strains and inactivates mycotoxins in the feed. Studies with rats indicated an increase in bone density after consumption of inulin/FOS. In addition, beneficial effects of inulin and oligofructose on bifidobacteria may lead to an improved absorption of B-complex vitamins. FOS is indicated during situations where natural bacterial levels

may be decreased. Oftentimes, this decrease in bacterial population may result in animals being off feed.

Other oligosaccharides are generally supplemented in animal diets to stimulate growth, improve meat quality, suppress diarrhea, and enhance immunity.

6. Patent intelligence search for yeast-based products

An electronic patent intelligence search on data from the yeast-based product market analysis was conducted using a comprehensive Delphion (Thomson Delphion ISI, Inc.) patent database. This database contains nearly all records of the U.S. Patent and Trademark Office, published patent applications, and nonpatent prior art search utilities. In addition, Derwent (a subsidiary of Thomson Inc.) patent databases were utilized to provide expanded titles for many new patents and patent application records. These expanded titles enhance readability of the patent data; however, it must be noted that this search provides only general information relating to intellectual property and should not be taken as a guarantee that a patent conflict does not exist.

The objectives of the patent intelligence search were to identify patents and patent applications that claim any elements relating to yeast-based products, to identify existing patents relating to yeast-based products, and to recognize patent applications that describe similar elements of patented inventions conflicting with the results presented. These results will include prior patented methods that perform a similar functional or mechanical process, as well as prior patented mechanisms that resemble or have similar components relating to yeast-based products. The results include prior patents that may be of interest to researchers or scientists engaged in developing novel yeast-based products (Table 10-12).

7. Implication

This literature review may serve as a valuable reference material for swine producers interested in understanding the potential role of yeast and yeast-based products in enhancing swine production and may serve as a starting point for basic and applied swine research studies. Understanding and determining possible options to further process an existing yeast product or develop other potential yeast-based products will allow swine nutritionists to better position these products and optimize their use in the feed industry. This manuscript provides swine producers with a database of yeast-based products that are available in the market and a catalog of specific yeast-based product patents.

Literature cited

AAFCO. 2005. Official Publication. Association of American Feed Control Officials, Inc., Atlanta, GA.

Aboobaker, V. S., A. D. Balgi, and R. K. Bhattacharya. 1994. *In vitro* effect of dietary factors on the molecular action of aflatoxin B_1: Role of non-nutrient phenolic compounds on the catalytic activity of liver fractions. In Vivo 8:1095-1098.

Alshaikh, M. A., M. Y. Alsiadi, S. M. Zahran, H. H. Mogawer, and T.A. Aalshowime. 2002. Effect of feeding yeast culture from different sources on the performance of lactating Holstein cows in Saudi Arabia. Asian-Aust. J. Anim. Sci. 15:352-356.

Amoikon, E. K., J. M. Fernandez, L. L. Southern, D. L. Thompson, Jr., T. L. Ward, and B. M. Olcott. 1995. Effect of chromium tripicolinate on growth, glucose tolerance, insulin sensitivity, plasma metabolites, and growth hormone in pigs. J. Anim. Sci. 73:1123-1130.

Anderson, R. A., M. M. Polansky, N. A. Bryden, E. E. Roginsky, W. Mertz, and W. Glinsmann. 1983. Chromium supplementation of human subjects: Effects on glucose, insulin, and lipid variables. Metabolism. 32(9):894-899.

Atroshi, T., A. Rizzo, I. Biese, M. Salonen, L. A. Lindberg, and H. Saloniemi. 1995. Effects of feeding T-2 toxin and deoxynivalenol on DNA and GSH contents of brain and spleen of rats supplemented with vitamin E and C and selenium combination. J. Anim. Phys. Anim. Nutr. 74:157-164.

Auclair, E. 2001. Yeast as an example of the mode of action of probiotics in monogastric and ruminant species. Pages 45-53 in Feed manufacturing in the Mediterranean region. Improving safety: from feed to food. Conference of feed manufacturers in the Mediterranean. Brufau, J. Ed.

Baldi, A., V. Bontempo, V. Dell'Orto, F. Cheli, F. Fantuz, and G. Savoini. 1999. Effects of dietary chromium yeast in weaning-stressed piglets. Can. J. Anim. Sci. 79:369-374.

Barnett, J. A. 2000. A history of research on yeasts 2: Louis Pasteur and his contemporaries, 1850-1880. Yeast 16:755-71.

Baudrimont, I., A. M. Betbeder, and E. E. Creppy. 1997. Reduction of the ochratoxin A-induced cytotoxicity in Vero cells by aspartame. Arch. Toxicol. 71:290-298.

Beer, M. U., E. Arrigoni, and R. Amadò. 1995. Effects of oat gum on blood cholesterol levels in healthy young men. Eur. J. Clin. Nutr. 49:517-522.

Bradley, G. L., and T. F. Savage. 1995. The influences of pre-incubation storage duration and genotype on the hatchability of medium white turkey eggs from hens fed a diet containing a yeast culture of *Saccharomyces cerevisiae*. Anim. Feed Sci. Tech. 51:141-152.

Britt, J. H., J. D. Armstrong, and N. M. Cox. 1988. Metabolic interfaces between nutrition and reproduction. Pages 117-125 in Proc. 11th Int. Congr. Anim. Reprod. Artificial Insemination., Dublin, Ireland.

Broderick, G. A., D. R. Mertens, and R. Simons. 2002. Efficacy of carbohydrate sources for milk production by cows fed diets based on alfalfa silage. J. Dairy Sci. 85:1767-1776.

Brown, G. D., and S. Gordon. 2001. A new receptor for β-glucans. Nature. 413:36-37.

Brown, G. D., and S. Gordon. 2003. Fungal β-glucans and mammalian immunity. Immunity. 19:311-315.

Brown, G. D., J. Herre, D. L. Williams, J. A. Willment, A. S. J. Marshall, and S. Gordon. 2003. Dectin-1 mediates the biological effects of β-glucans. J. Exp. Med. 197:1119-1124.

Bruerton, K. 2001. Finding practical solutions to mycotoxins in commercial production: a nutritionist's perspective. Pages 161-168 in Biotechnology in the Feed Industry. Proc. of the 17th Annual Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, UK.

Bustamante, S. A., N. Sanchez, J. Crosier, D. Miranda, G. Colombo, and M. J. S. Miller. 1994. Dietary nucleotides: effects on the gastrointestinal system in swine. J. Nutr. 124:149-156.

Buts, J. P., N. De Keyser, and L. De Raedemaeker. 1994. *Saccharomyces boulardii* enhances rat intestinal enzyme expression by endoluminal release of polyamines. Pediatr. Res. 36:522-527.

Callaway, E. S., and S. A. Martin. 1997. Effects of a *Saccharomyces cerevisiae* culture on ruminal bacteria that utilize lactate and digest cellulose. J. Dairy Sci. 80:2035-2044.

Cameron, B. F., C. W. Wong, G. N. Hinch, D. Singh, J. V. Nolan, and I. G. Colditz. 2001. Effects of nucleotides on the immune function of early-weaned pigs. Pages 66-68 in Digestive Physiology of Pigs. Proc. 8th Symposium. J. E. Lindberg and B. Ogle, eds. CABI Publishing New York, NY.

Carlson, M. S., T. L. Veum, J. R. Turk, D. W. Bollinger, and G. W. Tibbets. 2001. A comparison between feeding either peptide or plasma proteins with or without a feed grade antibiotic on growth performance and intestinal health. University of Missouri research data. (Unpublished).

Carver, J. D., and W. A. Walker. 1995. The role of nucleotides in human nutrition. Nutr. Biochem. 6:58-72.

Castagliuolo, I., M. F. Rieger, L. Valenick, J. I. Lamont, C. Pothoulakis. 1999. *Saccharomyces boulardii* protease inhibits the effects of *Clostridium difficile* toxins A and B in human colonic mucosa. Infect. Immun. 67:302-307.

Chang, X., and D. N. Mowat. 1992. Supplemental chromium for stressed and growing feeder calves. J. Anim. Sci. 70:559-565.

Chen, D., and A. J. Ainsworth. 1992. Glucan administration potentiates immune defense mechanisms of channel catfish, *Ictalurus punctatus* Rafinesque. J. Fish Dis. 15:295-304.

Dashwood, R., T. Negishi, H. Hayatsu, V. Breinholt, J. Hendricks, and G. Bailey. 1998. Chemopreventative properties of chlorophylls toward aflatoxin B_1: A review of the antimutagenicity and anticarcinogenicity data in rainbow trout. Mutat. Res. 399:245-514.

Davis, C. M., K. H. Sumrall, J. B. Vincent. 1996. A biologically active form of chromium may activate a membrane phosphotyrosine phosphatase (PTP). Biochem. 35:12963-12969.

Davis, M. E., C. V. Maxwell, D. C. Brown, B. Z. de Rodas, Z. B. Johnson, E. B. Kegley, D. H. Hellwig, and R. A. Dvorak. 2002. Effect of dietary mannan oligosaccharides and (or) pharmacological additions of copper sulfate on growth

performance and immunocompetence of weanling and growing/finishing pigs. J. Anim. Sci. 80:2887- 2894.

Dawson, K. A., J. Evans, and M. Kudupoje. 2001. Understanding the adsorption characteristics of yeast cell wall preparations associated with mycotoxin binding. Pages 169-181 in Biotechnology in the Feed Industry. Proc. of the 17th Annual Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, UK.

Decuypere, J., N. Dierick, and S. Boddez. 1998. The potentials for immunostimulatory substances (β-1, 3/1, 6 glucans) in pig nutrition. J. Anim. Feed Sci. 7:259-265.

Devegowda, G., B. I. R. Aravind, K. Rajemdra, M. G. Morton, A. Baburathna, and C. Sudarshan. 1994. A biological approach to counteract aflatoxicosis in broiler chickens and ducklings by the use of *Saccharomyces cerevisiae* cultures added to the feed. Pages 235-245 in Biotechnology in the Feed Industry. Proc. of the 10th Annual Symposium T. P. Lyons and K. A. Jacques eds. Nottingham University Press, UK.

Dritz, S. S., J. Shi, T. L. Kielian, R. D. Goodband, J. L. Nelssen, M. D. Tokach, M. M. Chengappa, J. E. Smith, and F. Blecha. 1995. Influence of dietary β-glucan on growth performance, non-specific immunity, and resistance to *Streptococcus suis* in weanling pigs. J. Anim. Sci. 73:3341-3350.

Ducluzeau, R., and M. Bensaada. 1982. Comparative effect of a single or continuous administration of *Saccharomyces boulardii* on the establishment of various strains of *Candida* in the digestive tract of gnotobiotic mice. Ann. Microbiol. 133:491-501. (Abstr.)

Edens, F. W. 2001. Involvement of Sel-Plex® in physiological stability and performance of broiler chickens. Pages 349-376 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 17th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Edens, F. W., and K. M. Gowdy. 2004. Selenium sources and selenoproteins in practical poultry production. Pages 36-55 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 20th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

El Hassan, S. M., C. J. Newbold, and R. J. Wallace. 1993. The effect of yeast culture on rumen fermentation: growth of the yeast in the rumen and the requirement for viable yeast cells. Anim. Prod. 56:463.

Elmer, G. W., and L. V. McFarland. 1987. Suppression by *Saccharomyces boulardii* of toxogenic *Clostridium difficile* overgrowth after vancomycin treatment in hamsters. Antimicrob. Agents Chemother. 31:129-131.

FDA. 1974. Food additives permitted in feed and drinking water of animals: selenium. Fed. Reg. 39:1355.

FDA. 1987. Food additives permitted in feed and drinking water of animals: selenium. Fed. Reg. 52:10887.

FDA. 2002. Food additives permitted in feed and drinking water of animals: selenium yeast. Fed. Reg. 67:46850.

Ferket, P. R., C. W. Parks, and J. L. Grimes. 2002. Mannan oligosaccharides *versus* antibiotics for turkeys. Pages 179-184 in Nutritional Biotechnology in the Feed

and Food Industries. Proc. of Alltech's 18th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Fortin, A., W. M. Robertson, S. Kibite, and S. J. Landry. 2003. Growth performance, carcass and pork quality of finisher pigs fed oat-based diets containing different levels of beta-glucans. J. Anim. Sci. 81:449-456.

Funderburke, D. W. 2002. Effects of dietary mannan oligosaccharides on performance of commercial sows and their litters. Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 18th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Gallin, J. 2002. A historical perspective on clinical research. Page 2 in Principles and Practice of Clinical Research. J. Gallin, ed. Academic Press, San Diego, CA.

Goeger, D. E., K. E. Anderson, and A. W. Hsie. 1998. Coumarin chemoprotection against aflatoxin B_1-induced mutation in a mammalian cell system: A species difference in mutagen activation and protection with chick and rat liver S9. Environ. Mol. Mutgen. 30:64-74.

Gourley, G. G., J. F. Lampe, J. C. Sparks, and T. T. Stumpf. 2005. Piglet survivability and performance: Sel-Plex® versus sodium selenite in sow and nursery diets. Pages 153-156 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 21st International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Grosse, Y., L. Chekir Ghedira, A. Huc, S. Obrecht Pfumio, G. Dirheimer, H. Bacha, and A. Pfohl Leszkowicz. 1997. Retinaol, ascorbic acid and alpha-tocopheroal prevent DNA adduct formation in mice treated with mycotoxins ochratoxin A and zealalenone. Cancer Lett. 114:225-229.

Hahn, T. W., J. D. Lohakare, S. L. Lee, W. K. Moon, and B. J. Chae. 2006. Effects of supplementation of beta-glucans on growth performance, nutrient digestibility, and immunity in weanling pigs. J. Anim. Sci. 84:1422-1428.

Hamuro, J., U. Hadding, and D. Bitter-Suermann. 1978. Solid phase activation of alternative pathway of complement by β-1,3-glucans and its possible role for tumor regressing activity. Immunology. 34:695-705.

Han, Y., and J. E. Cutler. 1995. Antibody response that protects against disseminated candidiasis. Infect. Immun. 63:2714-2719.

Hemken, R. W., R. J. Harmon, and S. Trammel. 1998. Selenium for dairy cattle: a role for organic selenium. Pages 497-503 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 14th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Hill, J., S. V. Tracey, M. Willis, L. Jones, and A. D. Ellis. 2001. Yeast culture in equine nutrition and physiology. Pages 97-114 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 17th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Hiss, S., and H. Sauerwein. 2003. Influences of dietary β-glucan on growth performance, lymphocyte proliferation, specific immune response, and haptoglobin concentrations in pigs. J. Anim. Physiol. a. Anim. Nutr. 87:2-11.

Hooge, D. M. 2004. Meta-analysis of broiler chicken pen trials evaluating dietary mannan oligosaccharide. Int. J. Poult. Sci. 3:163-174.

Huegten, E. V., D. W. Funderburke, and K. L. Dorton. 2003. Growth performance, nutrient digestibility, and fecal microflora in weanling pigs fed live yeast. J. Anim. Sci. 81:1004-1012.

Huff, G. R., W. E. Huff, and J. M. Balog. 2002. Effect of dietary treatment with β-1,3/1,6-glucan (Immustim) on disease resistance of turkeys challenged with *Escherichia coli*. Poult. Sci. 81(Suppl. 1) (Abstr.).

Huff, G. R., W. E. Huff, J. M. Balog, N. C. Rath, and A. K. Bahl. 2002. Effect of dietary treatment with ß-1,3/1,6-glucan (Immustim) on disease resistance of turkeys challenged with *Escherichia coli*. Poultry Science 81 (Suppl. 1).

Hunt, C. D., and B. J. Stoecker. 1996. Deliberations and evaluations of the approaches, endpoints and paradigms for boron, chromium and fluoride dietary recommendations. J. Nutr. 126(Suppl.):2441S-2451S.

Ibeh, I. N., and D. K. Saxena. 1998. Effect of alpha-tocopherol supplementation on the impact of aflatoxin B_1 on the testes of rats. Exp. Toxicol. Pathol. 50:221-224.

Institute, N. H. G. R. 1996. International Team Completes DNA Sequence of Yeast. In N. H. G. R. Institute (ed.), vol. 2005. National Human Genome Research Institute.

Junka, V., and A. Shimkus. 2002. The effect of the probiotics Yeasture and Microbond on pigs' growth. Lithuanian Veterinary Academy, Kaunas, Lithuania.

Jurgens, M. H., R. A. Rikabi, and D. R. Zimmerman. 1997. The effect of active dry yeast supplementation on performance of swine during gestation-lactation and their pigs. J. Anim. Sci. 75:593-597.

Kataoka, K., T. Muta, S. Yamazaki, and K. Takeshige. 2002. Activation of macrophages by linear (1,3)-β-D-glucans. J. Biol. Chem. 277:36825-36831.

Khajarern, J., and S. Khajarern. (unpublished) Efficacy of Microbond (natural growth promoter) for aflatoxin binder in weaning pigs. Department of Animal Science, Faculty of Agriculture, Khon Kaen University, Thailand.

Kincaid, R. L., M. Rock, and F. Awadeh. 1999. Selenium for ruminants: comparing organic and inorganic selenium for cattle and sheep. Pages 537-545 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 15th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Kocher, A., and L. Tucker. 2005. The "gut health" response to dietary Bio-Mos®: effects on gut microbiology, intestinal morphology, and immune response. Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 21st International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Kokoshis, P. L., D. L. Williams, J. A. Cook, and N. R. Di Luzio. 1978. Increased resistance to *Staphylococcus aureus* infection and enhancement in serum lysozyme activity by glucan. Science. 199:1340-1342.

Kornegay, E. T., D. Rhein-Welker, and M. D. Lindemann. 1994. Performance and nutrient digestibility in weanling pigs as influenced by peanut hull and yeast culture additions to starter diets. J. Anim. Sci. 72(Suppl. 1):6.

Kornegay, E. T., D. Rhein-Welker, M. D. Lindemann, and C. M. Wood. 1995. Performance and digestibility in weanling pigs as influenced by yeast culture additions to starter diets containing dried whey or one of two fiber sources. J. Anim. Sci. 73:1381-1389.

Kornegay, E. T., Z. Wang, C. M. Wood, and M. D. Lindemann. 1997. Supplemental chromium picolinate influences nitrogen balance, dry matter digestibility, and carcass traits in growing-finishing pigs. J. Anim. Sci. 75:1319-1323.

Ledoux, D. R., and G. E. Rottinghaus. 1999. *In vitro* and *in vivo* testing of adsorbents for detoxifying mycotoxins in contaminated feedstuffs. Pages 369-379 in Biotechnology in the Feed Industry. Proc. of the 15th Annual Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, UK.

Lee, J. H., Y. B. Lim, K. M. Park, S. W. Lee, S. Y. Baig, and H. T. Shin. 2003. Factors affecting oxygen uptake by yeast *Issatchenkia orientalis* as microbial feed additive for ruminants. Asian-Aust. J. Anim. Sci. 16:1011-1014.

LeMieux, F. M., L. L. Southern, and T. D. Bidner. 2003. Effect of mannan oligosaccharides on growth performance of weanling pigs. J. Anim. Sci. 81:2482-2487.

Lemme, A., C. Wenk, M. Lindemann, and G. Bee. 2000. Chromium yeast affects growth and plasma traits but not carcass characteristics of growing-finishing pigs depending on the glycemic index. Arch. Tierernahr. 53(2):157-177.

Li, J., D. F. Li, J. J. Xing, Z. B. Cheng, and C. H. Lai. 2006. Effects of beta-glucan extracted from *Saccharomyces cerevisiae* on growth performance, and immunological and somatotropic responses of pigs challenged with *Escherichia coli* lipopolysaccharide. J. Anim. Sci. 84:2374-2381.

Lin, Z. H., S. G. Li, L. Y. Wu, S. Sun, and Q. W. Lu. 1994. Antagonistic effect of Se on the T-2 toxin-induced changes in the ultrastructure and mitochondrial function of cultured chicken embryonic chondrocytes. J. Clin. Biochem. Nutr. 17:119-132.

Lindemann, M. D. 1996. Organic chromium - The missing link in farm animal nutrition? Pages 299-314 in Biotechnology in the Feed Industry: Proc. of Alltech's 12th Ann. Symp. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Loughborough, Liecs. UK.

Lindemann, M. D., C. M. Wood, A. F. Harper, E. T. Kornegay, and R. A. Anderson. 1995. Dietary chromium picolinate additions improve gain:feed and carcass characteristics in growing-finishing pigs and increase litter size in reproducing sows. J. Anim. Sci. 73:457-465.

Lovell, R. T., and C. Wang. 1997. Comparison of organic and inorganic sources of selenium for growth and health of channel catfish. Pages 165-179 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 13th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Lynch, H. A., and S. A. Martin. 2002. Effects of *Saccharomyces cerevisiae* culture and *Saccharomyces cerevisiae* live cells on *in vitro* mixed ruminal microorganism fermentation. J. Dairy Sci. 85:2603-2608.

Mahan, D. C. 1999. Organic selenium: using nature's model to redefine selenium supplementation for animals. Pages 523-535 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 20th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Mahan, D. C. 2004. The role of selenium and Sel-Plex ® in sow reproduction. Pages 132-139 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of

Alltech's 20th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Mahan, D. C. and J. C. Peters. 2004. Long-term effects of dietary organic and inorganic selenium sources and levels on reproducing sows and their progeny. J. Anim. Sci. 82:1343-1358.

Mahan, D. C., T. R. Cline, and B. Richert. 1999. Effects of dietary levels of selenium-enriched yeast and sodium selenite as selenium sources fed to growing-finishing pigs on performance, tissue selenium, serum glutathione peroxidase activity, carcass characteristics, and loin quality. J. Anim. Sci. 77:2172-2179.

Mahan, D. C., and Y. Y. Kim. 1996. Effect of inorganic or organic selenium at two dietary levels on reproductive performance and tissue selenium concentrations in first parity gilts and their progeny. J. Anim. Sci. 74:2711-2718.

Mao, X. F., X. S. Piao, C. H. Lai, D. F. Li, J. J. Xing, and B. L. Shi. 2005. Effects of beta-glucan obtained from the Chinese herb *Astragalus membranaceus* and lipopolysaccharide challenge on performance, immunological, adrenal, and somatotropic responses of weanling pigs. J. Anim. Sci. 83:2775-2782.

Maribo, H. 2003. Weaning pigs without antibiotic growth promoters: strategies to improve health and performance. Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 19th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Mateo, C. D., D. N. Peters, and H. H. Stein. 2004. Nucleotides in sow colostrum and milk at different stages of lactation. J. Anim. Sci. 82:1339-1342.

Mateo, C. D. 2005. Aspects of nucleotide nutrition in pigs. Ph.D. Diss., South Dakota State University, Brookings.

Mathew, A. G., S. E. Chatten, C. M. Robbins, and D. A. Golden. 1998. Effects of a direct-fed yeast culture on enteric microbial populations, fermentation acids, and performance of weanling pigs. J. Anim. Sci. 76:2138-2145.

Melby, Jr., E. 1987. Overview of the state of the art in development and utilization of animal models in the U.S.A. Pages 1-10 in Progress in Clinical and Biological Research. J. Kawamata and E. Melby, Jr, eds. Liss, Inc., New York, NY.

Miguel, J. C., S. L. Rodriguez-Zas, and J. E. Pettigrew. 2002. Practical response to BioMos® in nursery pigs: a meta-analysis. Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 18th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Moonsie-Shageer, S., and D. N. Mowat. 1993. Effect of level of supplemental chromium on performance, serum constituents, and immune status of stressed feeder calves. J. Anim. Sci. 71:232-238.

Mordenti, A., A. Piva, and G. Piva. 1997. The European perspective on organic chromium in animal nutrition. Pages 227-240 in Biotechnology in the Feed Industry: Proc. of Alltech's 13th Ann. Symp. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Loughborough, Liecs. UK.

Mowat, D. N. 1997. Organic chromium in animal nutrition. Pages 2-47 in Chromium books. Guelph, Ontario, Canada.

Murphy, J. 2002. No easy answers to the mycotoxin dilemma. Ontario Ministry of Food and Rural Affairs website. Available:

http://www.omafra.gov.on.ca/english/livestock/swine/facts/mycodilem.htm Accessed Jul. 26, 2006.

Murray, A. C. 1994. Effect of yeast culture on performance, carcass composition, and mechanical properties of bones in swine. J. Anim. Sci. 72(Suppl. 2):5.

Murray, A. C., and D. L. Dawe. 1996. Supplemental yeast culture on reproductive performance and apparent nutrient digestibilities of sows and gilts. J. Anim. Sci. 74(Suppl. 1):187.

Newman, K. E. 1995. *Saccharomyces boulardii*: more applications for yeast culture in monogastrics. Pages 379-381 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 11th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

O'Carra, R. 1998. Boosting immune response in dogs: a role for dietary mannan sugars. Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 14th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Okada, S., H. Tsukada, and M. Tezuka. 1989. Effect of chromium (III) on nucleolar RNA synthesis. Biol. Trace Elem. Res. 21:35-39.

Ott, E. A. 2005. Influence of Bio-Mos ®, a mannan oligosaccharide supplement, on the immune system of the mare and neonatal foal. Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 21st International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Pagan, J. D., P. Karnezos, M. A. P. Kennedy, T. Currier, and K. E. Hoekstra. 1999. Effect of selenium source on selenium digestibility and retention in exercised thoroughbreds. Pages 579-585 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 15th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Page, T. G., L. L. Southern, T. L. Ward, and D. L. Thompson, Jr. 1993. Effect of chromium picolinate on growth and serum and carcass traits of growing-finishing pigs. J. Anim. Sci. 71:656-662.

Piva, G., F. Galvano, A. Pietri, and A. Piva. 1995. Detoxification methods of aflatoxins. A review. Nutr. Res. 5:689-715.

Plat, J., and R. P. Mensink. 2005. Food components and immune function. Curr. Opin. Lipidol. 16:31-37.

Poutsiaka, D. D., M. Mengozzi, E. Vannier, B. Sinha, and S. A. Dinarello. 1993. Cross-linking of the β-glucan receptor on human monocytes results in interleukin-1 receptor antagonist but not interleukin-1 production. Blood. 82:3695-3700.

Prelusky, D. B., B. A. Rotter, B. K. Thompson, and H. L. Trenholm. 1997. Effects of appetite stimulant cyproheptadine on deoxynivalenol-induced reductions in feed consumption and weight gain in the mouse. J. Environ. Sci. and Health. 32:429-448.

Qamar, A., S. Aboudola, M. Warney, P. Michetti, C. Pothoulakis, J. T. LaMont, and C. P. Kelly. 2001. *Saccharomyces Boulardii* stimulates immunoglobulin A immune response to *Clostridium difficile* toxin A in mice. Infect. Immun. 69:2762-2765.

Reen, R. K., F. L. Wielbel, and J. Singh. 1997. Piperine inhibits aflatoxin B_1-induced cytotoxicity and genotoxicity in V79 Chinese hamster cells genetically engineered to express rat cytochrome P4503B. J. Ethnopharmacology 58:165-173.

Reyes, J. C., M. R. Ellersieck, and T. L. Veum. 1991. Effect of yeast culture in sow diets on apparent nutrient digestibilities and reproductive performance. J. Anim. Sci. 69(Suppl. 1):378.

Rodrigues, A. C, R. M. Nardi, E. A. Bambirra, E. C. Vieira, and J. C. Nicoli. 1996. Effect of *Saccharomyces Boulardii* against experimental oral infection with *Salmonella typhimurium* and *Shigella flexneri* in conventional and gnotobiotic mice. J. Appl. Bacteriol. 81:251-256.

Rotruck, J. T., A. L. Pope, H. E. Ganther, A. B. Swanson, D. G. Hafeman, and W. G. Hoekstra. 1973. Selenium: Biochemical role as a component of glutathione peroxidase. Science. 179:588-590.

Rozeboom, D. W., D. T. Shaw, R. J. Tempelman, J. C. Miguel, J. E. Pettigrew, and A. Connolly. 2005. Effects of mannan oligosaccharide and an antimicrobial product in nursery diets on performance of pigs reared on three different farms. J. Anim. Sci. 83:2637-2644.

Ruiz-Herrera, J. 1991. Biosynthesis of β-glucans in fungi. Antonie van Leeuwenhoek. (Abstr.) 60:72-81.

Salama, A. A. K., G. Caja, D. Garín, E. Albanell, X. Such, and R. Casals. 2002. Effects of adding a mixture of malate and yeast culture (*Saccharomyces cerevisiae*) on milk production of Murciano-Granadina dairy goats. Anim. Res. 51:295-303.

Schwartz, K., and C. M. Foltz. 1957. Selenium as an integral part of factor 3 against dietary necrotic liver degeneration. J. Am. Chem. Soc. 79:3292-3293.

Schwartz, K., and W. Mertz. 1957. A glucose tolerance factor and its differentiation from factor 3. Arch. Biochem. Biophys. 72:515-518.

Shields, R. G., Jr. 1997. Organic chromium: Potential applications in pet food formulations. Pages 251-267 in Biotechnology in the Feed Industry: Proc. of Alltech's 13th Ann. Symp. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Loughborough, Liecs. UK.

Smith, T. K., S. R. Chowdhury, and H. V. L. N. Swamy. 2004. Comparative aspects of *Fusarium* mycotoxicosis in broiler chickens, laying hens and turkeys and the efficacy of a polymeric glucomannan mycotoxin adsorbent: Mycosorb®. Pages 103-109 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of the 20th Annual Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, UK.

Spring, P. 1995. Competitive exclusion of Salmonella using bacterial cultures and oligosaccharides. Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 11th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Spring, P., and M. Privulescu. 1998. Mannanoligosaccharide: its logical role as a natural feed additive for piglets. Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 14th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Spring, P., C. Wenk, K. A. Dawson, and K. E. Newman. 2000. The effects of dietary mannanoligosaccharides on cecal parameters and the concentrations of enteric

bacteria in the ceca of Salmonella-challenged broiler chicks. Poult. Sci. 79:205-211.

Staykov, Y., P. Spring, and S. Denev. 2005. Influence of dietary Bio-Mos® on growth, survival, and immune status of rainbow trout (*Salmo gairdneri irideus* G.) and common carp (*Cyprinus carpio* L.). Pages 179-184 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 21st International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Sutton, J. D., M. S. Dhanoa, S. V. Morant, J. France, D. J. Napper, and E. Schuller. 2003. Rates of production of acetate, propionate, and butyrate in the rumen of lactating cows given normal and low-roughage diets. J. Dairy Sci. 86:3620-3633.

Swamy, H. V., T. K. Smith, E. J. MacDonald, H. J. Boermans, and E. J. Squires. 2002. Effects of feeding a blend of grains naturally contaminated with Fusarium mycotoxins on swine performance, brain regional neurochemistry, and serum chemistry and the efficacy of a polymeric glucomannan mycotoxin adsorbent. J. Anim. Sci. 80:3257-3267.

Torrent, J. 1996. Selenium yeast and pork quality. Pages 161-164 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 12th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Van Heugten, E., and J. W. Spears. 1997. Immune response and growth of stressed weanling pigs fed diets supplemented with organic or inorganic forms of chromium. J. Anim. Sci. 75:409-416.

Veum, T. L., J. Reyes, and M. Ellersieck. 1995. Effect of supplemental yeast culture in sow gestation and lactation diets on apparent nutrient digestibilities and reproductive performance through one reproductive cycle. J. Anim. Sci. 73:1741-1745.

Voet D., and J. G. Voet. 1995. Nucleotide Metabolism. Pages 795-797 in Biochemistry. 2nd ed., N. Rose, ed. John Wiley and Sons, Inc. New York, NY.

Vohra, A., and T. Satyanarayana. 2001. Phytase production by the yeast, *Pichia anomala*. Biotechnol. Lett. 23:551-554.

Wallace, R. J. 1996. The mode of action of yeast culture in modifying rumen fermentation. Pages 217-232 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of Alltech's 12th International Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, Nottingham, UK.

Wenk, C., S. Gebert, and H. P. Pfirter. 1995. Chromium supplements in the feed for growing pigs and meat quality. Arch. Tierernahr. 48(1-2):71. (Abstr.)

White, L. A., M. C. Newman, G. L. Cromwell, and M. D. Lindemann. 2002. Brewers dried yeast as a source of mannan oligosaccharides for weanling pigs. J. Anim. Sci. 80:2619-2628.

Whitlow, L. W., W. M. Hagler, B. A. Hopkins, Jr., and D. E. Diaz. 2006. Mycotoxins in feeds and their effects on dairy cattle. ADM Alliance Nutrition website. Available: www.admani.com/alliancedairy/TechBulletins/Mycotoxins%20in%20feeds.htm. Accessed July 26, 2006.

Williams, D. L. 1997. Overview of (1,3)-β-D-glucan immunobiology. Mediat. Inflamm. 6:247-250.

Yiannikouris, A., G. Bertin, and J. P. Jouany. 2005. Reducing mycotoxin impact: the science behind Mycosorb®. Pages 265-276 in Nutritional Biotechnology in the Feed and Food Industries. Proc. of the 21st Annual Symposium. T. P. Lyons and K. A. Jacques, eds. Nottingham University Press, UK.

Yoon, I., and E. McMillan. 2006. Comparative effects of organic and inorganic selenium on selenium transfer from sows to nursing pigs. J. Anim. Sci. 84:1729-1733.

Zomborsky-Kovacs, M., S. Tuboly, H. Biro, L. Bardos, P. Soos, A. Toth, and G. Tornyos. 1998. The effect of β-carotene and nucleotide base supplementation on haematological, biochemical and certain immunological parameters in weaned pigs. J. Anim. and Feed Sci. 7:245-251.

Table 1. Common dried yeast products

Product	Description
Active dried Yeast	Composed of small and dry pellets. Compressed yeast is extruded through a plate containing numerous small holes. Frequent cuts are made forming small pellets. The pellets are then passed through numerous chambers of increasing temperature to remove excess water.
Brewers dried yeast	A byproduct of ethanol production in the beer and liquor industries. It is composed of dried and killed yeast biomass that can be used in food and feed markets.
Compressed yeast	Also referred to as cake, wet, or fresh yeast and is concentrated by passage through a filter press or rotary vacuum system. It is then extruded through a nozzle and cut into predetermined lengths to give the desired weight and size.
Fluid bed dried yeast	Fluid-bed drying refers to a drying technique that can produce a wide range of uniformly sized particles. Air flow and heat are used to form a liquid-like state.
Phaffia yeast	A product from *Phaffia rhodozyma* that produces the carotenoid astaxanthin (3, 3'-dihydroxy, β, β, carotene-4, 4'-dione). Astaxanthin imparts a reddish color to the tissues of fish that is aesthetically pleasing, especially for salmon.
Primary dried yeast	Yeasts grown for specific nutrient properties and not derived from another industry are referred to as primary dried yeasts. They are grown and then dried at high temperatures that kill the yeast. The end product is used for food enrichment.
Rotolouver dried yeast	Yeast is dried creating a "core" of live yeast surrounded by a "shell" of inactive yeast. This extremely nonporous shell provides protection to the live yeast core from heat and oxidation.
Torula dried yeast	Torula yeast is derived from *Candida utilis* and is primarily utilized in the paper industry. The yeast is grown in waste water referred to as sulfite liquor. Sulfite liquor is high in 5-carbon-ring structures and reduces the oxygen demand of the water, which is a necessary step in the process of waste-water treatment. The resulting yeast biomass product is used in the food industry.
Tunnel dried yeast	Compressed yeast is continuously introduced into a rolling drum. The rate of passage, tumbling, and temperature throughout the drum are controlled to obtain the desired dehydration of the product.

Table 2. Challenge models used in assessing the efficacy of yeast-based products

Yeast-based product	Animal	Animal subcategory	Pathogenic challenge model	Response criteria	Reference
Active dried yeast	Mice		*Candida* sp.	Colonization of pathogenic yeast	Ducluzeau and Bensaada,1982
Active dried yeast	Mice		*Salmonella typhimurium* and *Shigella flexneri*	Inhibitory effects on toxins; immunoglobulin concentration; mortality	Rodrigues et al., 1996
Active dried yeast	Mice		*Clostridium difficile* toxins A and B	Inhibitory effects on toxins; immunoglobulin concentration; mortality	Castaglioulo et al., 1999; Qamar et al., 2001
B-glucan	Mice		*Staphylococcus aureus* (intravenous challenge)	Macrophage hyperplasia and phagocytosis; serum lysozyme activity; mortality	Kokoshis et al., 1978
B-glucan	Swine	Weanling pigs	*Streptococcus suis*	IL-1 inhibition; mortality	Dritz et al., 1995; Hiss and Sauerwein, 2003
B-glucan	Swine	Weanling pigs	Environmental Stress (hygiene)	Performance	Decuypere et al., 1998
B-glucan	Poultry	Turkeys	*Escherichia coli* (respiratory challenge)	Performance; mortality	Huff et al., 2002
B-glucan	Swine	Weanling pigs	LPS	Performance	Mao et al., 2005
B-glucan	Swine	Barrows	Con-A, Phytohemagglutinin,	Lymphocyte proliferation index;	Li et al., 2006

			and LPS	IL-6; IL-10; TNF-α	
Cr yeast	Swine	Weanling pigs	ACTH	Insulin, cortisol, neutrophil superoxide, non-esterified fatty acid, and blood glucose concentration	Baldi et al., 1999
MOS	Poultry	Broiler birds	*Salmonella montevideo, S. give, S. kedougou, S. Dublin; 5 E. coli strains; 7* strains *of S. enteritidis* and *S. typhimurium; Campylobacter jejuni* and *C. coli*	*In vitro* agglutination of bacteria	Spring et al., 2000
Yeast culture	Hamsters		*Clostridium difficile*	Bacterial colonization; toxin concentration	Elmer and McFarland, 1987
Yeast glucomannan	Swine	Weanling pigs	Aflatoxin	Performance	Khajarern and Khajarern, unpublished data
Yeast nucleotides	Swine	Weanling pigs	Ischemia-reperfusion	Protective effect against ischemia-reperfusion	Bustamante et al., 1994
Yeast nucleotides	Swine	Weanling pigs	Phytohaemagglutinin and Con-A	Lymphocyte stimulation	Zomborsky-Kovacs et al., 1998
Yeast nucleotides	Swine	Weanling pigs	Nonspecific T-cell mitogen	Lymphocyte function; T-cell mediated DTH response to KLH	Cameron et al., 2001

				and *in vitro* proliferative response	
Yeast nucleotides	Swine	Weanling pigs	*Escherichia coli*	Performance	Maribo, 2003; P. Spring, unpublished data
Yeast nucleotides	Swine	Finisher pigs	Stress induced by transport and slaughter	Serum creatine kinase, lactate dehydrogenase, and AST concentration	M. Zomborsky, unpublished data

Table 3. Key words and phrases used in market analysis of yeast-based products

Yeast-based products	Key words and phrases
Active dried yeast	active dried yeast; tunnel dried; fluid bed dried; rotolouver dried
Yeast culture	yeast cultures; innovative yeast products; agricultural; agriculture; swine; livestock
Nutritional yeast	nutritional yeast; primary dried; brewers dried; torula dried; whey yeast; phaffia; irradiated
Yeast-based minerals	yeast based products; chromium; selenium; iron; zinc
Yeast fractions	yeast fractions; yeast cell walls; yeast hulls; yeast ghosts; livestock feed; yeast beta glucans; yeast mannan; yeast glucomannan; yeast autolysates; yeast extracts; yeast nucleotides
Other related yeast-based products	Enzymes; yeast; *Saccharomyces cerevisiae*; mannanoligosaccharides; fructooligosaccharides; a-galactooligosaccharides; transgalactooligosaccharides

Existing branded yeast-based products

Table 4. Active dried yeast

Active Feed Dry Yeast	**ACTIVE FEED DRY YEAST**	
	Company/Manufacturer:	Angel Yeast Co., LTD-China http://www.angel.com.cn/tj/feed/Active%20Feed%20Dry%20Yeast.pdf
	Description:	Uses a high-quality yeast strain containing various nutrients and growth factors. The product has high bioactivity, adapts to submerged aerobic fermentation and sterile processing, and primarily is used for stockbreeding.
	Dosage:	100-250 g/ ton of complete feed
	Packaging:	10 kg bag
Fluid bed dried yeast	**ACTIVE DRIED YEAST**	
	Company/Manufacturer:	Cypress Systems, Inc., Fresno, CA. http://www.cypsystems.com/product/active.html#product
	Description/Composition:	CP, min. 45%; 16 total AA; B vitamins; 10 essential trace minerals. Product has been fluid bed dried into short noodles that are easy to handle and free of dust or powder. Greater than 99% of the product is *S. cerevisiae* and less than 1% is an emulsifier that has been added to facilitate the drying process. Live yeast cell count of 1 x 10^{10}, or 1 billion live cells/g.
	Dosage:	1-3 ppm
	Packaging:	25 lb box
Rotolouver dried yeast	**ADY 20**	

	Company/Manufacturer:	Yeast Corporation, Milwaukee, WI. http://www.lesaffreyeastcorp.com/nutritional/index.html
	Distributor:	Prince Agri Products, Quincy, IL http://www.princeagri.com/productdetails.asp?id=2307
	Description:	ADY is undiluted and consists of 100% dried yeast cells. It has an approximate live cell count of 10 to 15 billion cells/g.
	Dosage:	2-4 lb/ton of complete feed
	Packaging	50 lb bag
	BIOSAF®	
	Company/Manufacturer:	SI Lesaffre-France http://www.saf-agri.com/english/yeastbio.htm
	Distributor:	Prince Agri-Products, Quincy, IL http://www.princeagri.com/productdetails.asp?id=2303
	Description:	Produced under ISO 9002 conditions. The product is dried using a proprietary method that creates a "core" of live yeast surrounded by a "shell" of inactive yeast. This extremely nonporous shell provides protection to the live yeast core from heat and oxidation. Consists of 100% yeast with no cereal fillers. A minimum of 8 billion CFU/g in the product is guaranteed.
	Dosage:	0.1-0.2 % of complete feed
	Packaging:	25 kg bag (40 bags/pallet); also comes in a powdered (tunnel-dried) formula - 15 kg box (45 boxes/pallet)
Tunnel dried yeast	**LEVUCELL SB®**	
	Company/Manufacturer/Distributor:	Lallemand http://www.lallemand.com/ANAH/eng/LevucellSB.shtm
	Description:	An active dry yeast that contains the CNCM (Pasteur Institute) I-1079 strain of *S. cerevisiae boulardii*.

	Dosage:	Levucell SB10ME: 100-200 g/ton of feed (gestating and lactating sows); 200-600 g/ton of feed (nursing and post-weaning pigs)
	Packaging:	20 kg box
	PROCREATIN 7®	
	Company/Manufacturer:	SAFMEX - Lesaffre Group, Toluca, Mexico http://www.saf-agri.com/english/yeastpro.htm
	Distributor:	Agri-Products, Quincy, IL http://www.princeagri.com/productdetails.asp?id=2304
	Description:	A specific strain of *S. cerevisiae* was selected for Procreatin-7® on the basis of numerous trials evaluating consistency of strain purity, consistent high live cell count initially and through storage, tolerance of the drying process, and tolerance of inhibitors (e.g. antibiotics, salt, minerals, etc.). Provides a consistent, high live yeast cell count to any nonpelleted livestock feed; water soluble, and effective in poultry watering systems or in dry milk replacer products. Has a live yeast cell count of 15 billion cfu/g.
	Dosage:	1-2 lb/ton of feed; Not recommended for use in pelleted feeds as temperatures may be reached that could harm the live yeast cells.
	Packaging:	50 lb bag

Table 5. Yeast culture

2X-2-2-5 LIVE CULTURE	***Company/Manufacturer/Distributor:***	Western Yeast Company, Chilicothe, IL http://www.westernyeast.com/wyprods.htm#StartofPage
	Description:	Active *S. cerevisiae* yeast grown and dormantized on ground yellow corn, corn gluten meal, condensed fermented corn extractives, cane molasses, and malted barley.
	Analysis:	CP, min. 11%; Crude Fat, min. 3%; Crude Fiber, max. 5%

	Dosage:	25-30 lb/ton of feed (pre-starter/starter/and sow late gestation and lactation diets); 20-25 lb/ton of feed (grower/finisher/and sow gestation diets)
	Packaging:	50 lb bag; available in bulk quantities
A-MAX®	***Company/Manufacturer:***	Varied Industries Corporation-ViCor http://www.vi-cor.com/amaxstd-analysis.php
	Description:	Yeast culture standard is *S. cerevisiae* yeast grown on a media of sucrose, cane molasses, and corn syrup, and processed grain byproducts.
	Dosage:	4 oz/head/day or 100-120 g/head/day
	Packaging:	50 lb bag
BIO ACTIVE YEAST	***Company/Manufacturer:***	Ultra Bio-Logics Corporation, Rigaud, Quebec http://www.ublcorp.com/; http://www.ctv.es/clean_world_hispania/feeds.htm
	Description:	The residual medium (i.e., molasses) on which selected strains are grown is completely washed and removed during harvesting. It is freeze-dried and vacuum-packed. Consists of a proprietary blend of pure *S. cerevisiae* strains.
	Dosage:	50-100 g/ton of feed for beef, dairy, swine, poultry, horse, fish, pet, and specialty feed.
	Packaging:	10 kg bag
BIO-AID S.Y.	***Company/Manufacturer:***	Ultra Bio-Logics Corporation Rigaud, Quebec http://www.ctv.es/clean_world_hispania/feeds.htm; http://www.ublcorp.com/
	Description:	A pure seaweed extract (*Yucca shidegera* extract) live active yeast culture. Contains ingredients that have the ability to inhibit urea hydrolysis (i.e., urease activity) resulting in 40-50% reductions of ammonia gas production in confinement operations.

	Dosage:	1-4 kg/ton of feed; 3-30 g/head/day (top dress)
	Packaging:	10 kg pail; 20 kg pail
BIOSPRINT	***Company/Manufacturer:***	Biosprint http://www.biosprint.co.uk/ Marketed by Scotmin Nutrition http://www.scotmin.com/products/index.html Registered by Prosol S.P.A. http://www.prosol-spa.it/index.asp Additional link: http://www.efsa.eu.int/science/feedap/feedap_opinions/183_en.html
	Description:	It is a specific strain of live yeast registered by Prosol S.P.A. and marketed by Scotmin Nutrition Ltd within the UK, Ireland and other countries. Biosprint has achieved Annex I (permanent) registration for growing pigs and Annex II registration (until 2008) for dairy cows.
CEL-CON YEAST CULTURE	***Company/Manufacturer:***	Western Yeast Company, Chilicothe, IL http://www.westernyeast.com/wyprods.htm#StartofPage
	Description:	A high potency live yeast culture with a low dietary inclusion rate. Active *S. cerevisiae* yeast is grown and dormantized on ground yellow corn, corn gluten meal, condensed fermented corn extractives, cane molasses, and malted barley.
	Analysis:	CP, min. 15%; Crude Fat, min. 3%; Crude Fiber, max. 5%
	Dosage:	3 lb/ton of feed (pre-starter/starter/and sow late gestation and lactation diets); 2 lb/ton of feed (grower/finisher/and sow gestation diets)
	Packaging:	50 lb bag; available in bulk quantities
DIAMOND V	***Company/Manufacturer/Distributor:***	Diamond V Mills, Inc., Cedar Rapids, IA

XPC™		http://www.diamondv.com/products/xpc.html
	Description:	Feed ingredient produced by fermenting selected liquid and cereal grain raw ingredients with bakers yeast (*S. cerevisiae*) and drying the entire culture-media without destroying the yeast factors, B-vitamins, and other fermentation products. A list of ingredients includes *S. cerevisiae* yeast grown on a media of processed grain by-products, roughage products, cane molasses, malt, and corn syrup.
	Analysis:	CP, min. 12%; Crude Fat, min. 1.0 %; Crude Fiber, max. 19.0 %
	Dosages:	0.2% (creep/starter/nursery diets); 0.1% (grower/finisher diets); 0.2% (sow gestation/lactation diets)
	Packaging:	50 lb bag
ENZION B 2000 PLUS	***Company/Manufacturer:***	Enzion Labs-A Division of Century Hill Industries, Inc., Roseville, CA http://enzion.com/products/hog/feedingBandE.aspx
	Description:	Enzion yeast cultures are designed to supply the necessary nutrients to feed protozoa, bacteria, and enzymes in the animal's digestive system that lower and maintain the system's pH. This product is prepared in a much different manner than most yeast products being marketed as it uses a mixture of yeast, vitamins, minerals, malt liquor, molasses, sugar, and other ingredients that are cultured on wheat bran, ground wheat, barley, oats, and corn. Additionally, it contains fermented whey solids. These solids use special bacteria to produce a type of lactic acid that has a low pH. This ingredient also contains 14 AA and 13 vitamins.
	Dosage:	4-5 g/head/day
	Packaging:	50 lb bag; 200 lb bag ; 200 lb drum
FERTRELL YEAST CULTURE	***Company/Manufacturer:***	Fertrell http://www.norganics.com/label/yeastculture.pdf

Composition: Dried *S. cerevisiae* fermentation product, corn DDGS, wheat middlings, animal digest, rice hulls, and Ca carbonate.

Dosage: 50 lb/ton (sow gestation and pig starter diets); 25 lb/ton (sow lactation and pig grower or finisher diets)

Packaging: 50 lb bag

HOG MATE®

Company/Manufacturer: Enzion Labs
http://enzion.com/products/hog/hogMate.aspx

Description: A nutritional livestock supplement of cultured *S. cerevisiae* yeast. Media on which it was grown consists of wheat bran, corn and corn meal germ, molasses, barley malt, barley DGGS, oats, barley, soybean meal, dried kelp, cane molasses, vitamins, and minerals.

Analysis: CP, min. 9%; Crude Fat, min. 3%; Crude Fiber, max. 18%

Dosage:

Pig weight, lb	ADFI, lb	Inclusion rate/ton of feed, %
Creep-25	1.00	4.50
26-50	2.75	3.25
51-80	3.50	2.50
81-120	4.50	2.00
120-market	7.00	1.25
SOWS		
Lactating	10.00	1.00
Gestating	5.00	1.75

Packaging: 50 lb bag; 200 lb fiber drums

JAYSON'S YEAST CULTURE

Company/Manufacturer: Jaysons Agritech Private Limited, India
http://www.zeusindia.net/jyc.html

Description: A combination of live yeast cells and their media rich in enzymes, peptides, minerals, growth-promoting factors, and immunostimulants.

	Composition:	Live yeast cells - 5 billion CFU/g
	Dosage:	250 g/ton (pig starter feed); 500 g/ton (pig grower/finisher feed); 500 g/ton (sow feed); 500 g/ton (poultry feed); 1kg/ton (cattle feed)
	Packaging:	500 g bag; 1kg bag; 25kg pouches or bag
MEDI PHARM CULTURES	***Company/Manufacturer:***	Medipharm-The Microcultural Specialists, Des Moines, IA http://www.medipharmusa.com/culture04.html http://www.arlafoods.com/
	Distributor:	Arla Foods Denmark (branch location in Oxford, NY)
	Description:	Gels may contain lactic acid-producing bacteria, such as *Enterococcus faecium* M 74® and *Lactobacillus acidophilus*, live cell yeast, such as *S. cerevisiae*, or other fermentation products derived from *Bacillus subtilis* or *Aspergillus oryzae*. Gels may also be supplemented with spray dried egg product, vitamins, minerals, enzymes, or other nutritional additives, such as Ca and propylene glycol.
	Dosage/Packaging:	Dial-A-Dose private labeled syringes are available in various sizes, including 15, 20, 30, 32, 60, and 80 cc. Also available are 300 cc snub-nosed or long tip syringes for multiple dosing of livestock using a dosing gun.
PROTOCOL YEAST CULTURES	***Company/Manufacturer:***	Protocol Technologies http://www.protocoltech.net/products.html#yeast
	Composition:	Contain stabilized, live, viable, ruminally active yeast cells and include yeast culture and yeast culture concentrate. Contains guaranteed live yeast cells with yeast culture at 180 billion cells/lb and yeast culture concentrate at 454 billion cells/lb.
SWINE-MATE	***Company/Manufacturer:***	Western Yeast Company http://www.westernyeast.com/wyprods.htm#StartofPage

	Description:	A direct fed microbial product that contains live cell yeast, fungal products, digestive enzymes, and 5 strains of live fermentation products.
	Analysis:	CP, min. 11%; Crude Fat, min. 2%; Crude Fiber, max. 5%
	Ingredients:	Active *S. cerevisiae* yeast grown and dormantized on ground yellow corn, corn gluten meal, condensed fermented corn extractives, cane molasses, malted barley, dried *Bacillus coagulans* fermentation product, dried *Bacillus licheniformis* fermentation product, dried *Bacillus subtilis* fermentation product, *Aspergillus oryzae* fermentation extract, *Streptococcus faecium*, Ca carbonate, a flavor agent, soy oil, and Na silico aluminate.
	Dosage:	Swine: 10 lb/ton (prestarter diet); 5 lb/ton (starter diet); 3-5 lb/ton (grower diet); 2.5 lb/ton (finisher diet); 5 lb/ton (sow gestation and lactation diets)
	Packaging:	25 lb bags
TURBOGROW 160™	***Company/Manufacturer:***	United Nutrients Corporation http://www.jefo.ca/fiches_anglais/turbogrow.html
	Description:	Dried yeast culture and its culture medium, dried *Aspergillus niger* fermentation product.
	Dosage:	2 kg/ton (prestarter and starter pig diets); 1 kg/ton (grower and finisher pig diets); 1 kg /ton (sow lactation diet)
	Packaging:	25 kg bag
ULTRA ACTIVE YEAST	***Company/Manufacturer:***	Ultratech Laboratories, Inc. http://www.ultrateck.net/yeasts.html
	Description:	Food grade live yeasts grown by aerobic fermentation; used in animal feeds in which the residual medium (molasses) on which selected yeast strains are grown, completely washed, and removed during harvesting. This process results in an increase in purity and quality available in animal feed yeasts. The product is vacuum-

		packed to conserve its microbiological properties.
	Dosage:	50-100 g/ton
YEA-SACC®1026	***Company/Manufacturer:***	Alltech, Inc., Lexington, KY http://www.alltech.com/About/yea-Sacc.htm
	Description:	Based on *S. cerevisiae* strain 1026
	Dosage:	10 g/head/day
	Packaging:	25 kg bag
YEASTURE	***Company/Manufacturer:***	Cenzone Tech Inc., San Marcos, CA http://www.cenzone.com/Eng/ENindex.html
	Description:	Broad spectrum feed additive composed of live *S. cerevisiae* yeast culture of high fermenting and reproductive capacity, lactic acid and enzyme producing bacteria, β-glucans, MOS, and colostrum.
	Dosage:	1-2 kg/ton of complete feed
	Packaging:	25 kg bag

Table 6. Nutritional yeast

Brewers dried yeast	**ACTIVE YEAST**	
	Distributor:	Labudde Group Inc., Grafton, WI. http://www.labudde.com/LaBudde_Group_TZspecs.htm#WHEY%20POWDER
	Description:	Contains *S. cerevisiae* yeast, ground yellow corn, hominy feed, corn gluten, wheat middlings, soybean meal, cane molasses, brewers dried yeast and brewers dried grains.
	Analysis:	CP, min. 15%; Crude Fat, min. 3%; Crude Fiber, max. 7%
	Dosage:	50 lb/ton (sow gestation diet); 25 lb/ton (sow lactation diet); 50 lb/ton (pig starter diet); 25 lb/ton (grower and finisher diets).
	Packaging:	50 lb bag

BGY28

Company/Manufacturer: F. L. Emmert Company
http://www.emmert.com/bgy28.shtml

Description: Fresh brewers yeast for livestock feed, pet food, and other applications. This product is economical, palatable, free-flowing, made with all natural ingredients, a natural ingredient binder, and is carefully produced from high-quality grains and yeasts.

Dosage: 4 oz/head/day

Packaging: 50 lb bag; 2,000 lb bulk bag; available in bulk

DINAFERM

Company/Manufacturer: Diversified Nutri-Agri Technologies, Inc. (Dinatec), Gainsville, GA
http://www.dinatec.com/dinaferm.htm

Description: Provides a full potency brewers yeast product from a specially selected strain of *S. cerevisiae* for all feed applications in an economical, palatable, and free-flowing form. The product is made by a unique process that dries the yeast at temperatures one-half or less than spray dried yeast. This exclusive process is made possible by the addition of a low-fiber fraction brewers grain carrier and assures full nutrient availability and outstanding palatability. This carrier not only allows the yeast to be dried at a much lower temperature, but also adds important nutritional components, outstanding dietary fiber, and excellent flow ability and handling characteristics to the product.

MYCOLACTOR®

Company/Manufacturer: Dinatec, Gainsville, GA
http://www.dinatec.com/2PGPRO~1/Mycolactor%20valid.htm

Description: Formulated to act as a probiotic and bind mycotoxins produced by mold organisms.

Dosage:	1 kg/ton of feed
Packaging:	Available in powder and liquid form for top dressing or mixing in feed; water-dispersible powders for top dressing or mixing in milk substitute or water.

PEKIN Brewers Dried Yeast 43-P

Company/Manufacturer:	Aventine Renewable Energy, Inc., Aurora, NE http://www.aventinerei.com/bio_products.htm#feed http://www.aventinerei.com/pdfs/43p_tech.pdf
Description:	It is a light tan inactive brewers yeast spray dried powder. Microbiological max.: standard plate count of 20,000/g; yeast and mold: 100/g; and also contains coliform organisms.
Analysis:	CP: 45%; Moisture: 6%; Max. pH (10% Solution): 4.3
Dosage:	2-5% of weanling and growing pig diets; 2 oz/head/day for breeding animals
Packaging:	2,000 lb bag; 50 lb bag

PROSPONSE®

Company/Manufacturer:	Alliance Animal Health http://www.admani.com/AllianceAnimalHealth/ProsponseYeast.htm
Description:	Yeast supplement for all classes of beef and dairy cattle, poultry, turkeys, horses, sheep, goats, starter and pigs. It is made by an exclusive process that ensures superior quality brewers yeast with outstanding palatability and a rich source of naturally occurring B-complex vitamins. It also contains an elevated level of highly digestible protein.
Dosage:	10-20 lb/ton of complete feed
Packaging:	50 lb bag

SHOWBLOOM

Company/Manufacturer:	F. L. Emmert Company

		http://www.emmert.com/showbloom/showbloom.shtml
	Description:	Combines the benefits of fresh brewers yeast with other natural ingredients, minerals, plant protein products, cane molasses, processed grain byproducts, Vit. A acetate, Vit. D_3 supplement, Vit. E supplement, ascorbic acid.
	Dosage:	4 oz/day
	Packaging:	25 lb pail; 40 lb tubs; 50 lb bag
	TURVAL 16 SWINE	
	Company/Manufacturer:	Turval Laboratories Pradamano, Italy http://www.turval.com/html/mcproducts.html
	Description:	An exclusive balanced mix of selected lactic yeasts, a wide range of cellular metabolites, milk serum, and hydrolyzed proteins. The action of TURVAL 16 SWINE is considerably different from that of the usual brewers yeasts and lactic ferments in that it effectively penetrates the gastric barrier due to the large content of chitin in their cellular wall.
	Dosage:	Weaning phase (up to 8 kg): 200g/ton of feed; phase I of post-weaning (from 8 to 15 kg): 200g/ton of feed; phase II of post-weaning (from 15 to 30 kg): 200g/ton of feed
	Packaging:	25 kg bag
Phaffia yeast	**ASTAXANTHIN**	
	Company/Manufacturer:	Igene Biotechnology, Inc., Columbia, MD http://www.igene.com/asta1.html
	Description:	Derived from the yeast *Phaffia rhodozyma*, which is a natural source of red pigment. It is a free-flowing granular powder that can be readily blended with other feed ingredients to meet formulator specifications. It is a natural source of protein and other nutrients and may replace vegetable or animal meal used in aquaculture feed.
	Dosage:	0.5 kg/100 kg of feed (salmon diets)

	Packaging:	10 kg box
Primary dried yeast	**FEED YEAST**	
	Company/Manufacturer:	Hebei Meihua Monosodium Glutamate Group Co., Ltd.-China http://www.made-in-china.com/china-products/productviewkiExUztDDmnh/Feed-Yeast.html
	Description:	A yellowish powder with a slight fragrance of yeast and CP content similar to animal protein concentrate. Contains increased levels of Vit. B and enzyme factors.
	Packaging:	20 kg bag
	FODDER YEAST	
	Company/Manufacturer:	CBH Qingdao Company Limited http://cbhcn.en.alibaba.com/product/50044211/50203330/PROTEINS/Fodder_Yeast__55___60___65__Feed_Grade_.html
	Description:	Fodder yeast is a single cell protein produced with cornstarch or brewers grain used as raw material through the technology of simultaneous saccharification and fermentation. The protein content is 50-65%, and the ratio of digestion is more than 90%. The fodder yeast is rich in proteins, fats, carbohydrates, AA, and B vitamins and possesses high energy value.
	Packaging:	25 kg bag; 40 kg bag
	NUTRIBIO	
	Company/Manufacturer:	Saf Agri - Lesaffre http://www.saf-agri.com/english/yeastlev.htm
	Description:	A powdered form of yeast (*S. cerevisiae*) that has been inactivated by heat treatment. It is a primary product made by spray drying a concentrated slurry of yeast cells.
	Analysis:	Moisture: 3-5%; Protein: 42-52%; Fat: 4-8%; Ash: 5-7%; Total

		carbohydrates: 34-44%
	Dosage:	Based on NRC requirements, no standard dosages
	Packaging:	50 lb bag (45 bags/pallet)
Whey yeast	**SUNSHINE PLUS™**	
	Company/Manufacturer:	Blue Seal Feeds, Inc., Londonderry, NH http://www.blueseal.com/barnyard/livestock/pig/pigfeeds2.htm
	Description:	A highly palatable and nutrient-rich conditioning supplement containing whey yeast culture and probiotics. Pelleted in texture and contains CP, min. 25%, Crude fat, min. 2%, and Crude fiber, max. 4%.
	Dosage:	0.25 lb/day [finisher (125lb BW to market), young and adult boar, bred gilt and sow diets]; 1.0 lb/day (sow lactation diet).
	Packaging:	25 lb bucket; 50 lb bag

Table 7. Yeast-based mineral products

Cr yeast	**AKROM**	
	Company/Manufacturer:	Lallemand Animal Nutrition, Milwaukee, WI http://www.lallemand.com/ANAH/eng/Alkrom.shtm
	Description:	Inactivated whole cell yeast (*S. cerevisiae*) product containing elevated levels of Cr. The yeast cream is pasteurized and spray dried.
	Analysis:	Cr, min. 2,000 mg/kg; CP, min. 40%
	Dosage:	100 g/1,000 kg (0.2 lb/ton) of complete feed to supply 0.2 ppm Cr
	Packaging:	50 lb bag
	CHROMAX®	
	Company/Manufacturer:	Prince Agri Products Inc., Quincy, IL. http://www.princeagri.com/chromax.asp
	Dosage:	Swine: 200 ppb in complete feed; use 1 lb/ton CHROMAX 0.04%

	Cr premix to supply 200 ppb Cr
Packaging:	50 lb/bag
CHROMISAC	
Company/Manufacturer:	Jaysons Agritech Private Limited, India http://www.zeusindia.net/chromisac.html
Description:	Cr-yeast complex
Composition:	2,000 ppm Cr in a yeast complex
Dosage:	Swine: 150g/ton (starter diet); 200g/ton (grower, finisher, and sow diets)
***Packaging*:**	25 kg bag
CHROMIUM YEAST	
Company/Manufacturer:	Saf Agri-Lesaffre Group, Milwaukee, WI http://www.saf-agri.com/english/yeastmin.htm
Description:	Cr yeast is a *S. cerevisiae* yeast strain specially cultivated on a beet-molasses medium enriched with Cr salt. It is inactivated by heat treatment and spray dried.
Analysis:	Cr content: 1,600 ppm, 90% is intracellular Cr; Protein: 41-53%; Carbohydrates: 35-43%; Lipids: 4-8%
Dosage:	Based on NRC requirements, no standard dosages
Packaging:	25 kg bag
DINAKROME®	
Company/Manufacturer:	Dinatec, Gainsville, GA http://www.dinatec.com/2PGPRO~1/DINAKR~1.htm
Description:	An organic trivalent preparation consisting of Cr yeast, *Yucca shidigera* extract, synthetic amorphous precipitated silica, and magnesium mica.
Dosage:	400-1000 g/ton for swine diets
Packaging:	55 lb bag; 55 lb drums; 55 lb pail

ORGANIC CHROMIUM YEAST

Company/Manufacturer: Ultratech Laboratories, Inc.
http://www.ultrateck.net/yeasts.html

Description: Cr yeast is food grade spray dried whole cell yeast of *S. cerevisiae* containing high levels of Cr. The yeast cream is pasteurized to prevent contamination and is spray dried for the highest quality and purity. This process allows the Cr to interact with the yeast cell components. Gentle processing conditions cause a natural chelating effect that preserves the level of highly available nutrients.

Dosage: 50-200 g/metric ton of complete feed

Packaging: 225 g jar; 25 kg bag

VETA-ORCHRO

Company/Manufacturer: Vetagri
http://www.vetagri.ca/products.php?category_id=CAT007

Description: Natural source of organic Cr and also contains dried yeast, distillers solubles, and roughage.

Dosage: 100-200 g/ton (swine, poultry, prawn, and fish diets); 10 g/head/day (livestock diets)

Packaging: 2 kg bag; 10 kg bag; 20 kg bag

Fe yeast

IRON YEAST

Company/Manufacturer: Saf Agri-Lesaffre Group Milwaukee, WI
http://www.saf-agri.com/english/yeastmin.htm

Description: Fe yeast is a *S. cerevisiae* yeast strain specially cultivated on a beet-molasses medium enriched with Fe salts. It is inactivated by heat treatment and spray dried.

Analysis: Fe content: 8,500 ppm, 85% is intracellular Fe; Protein: 41-47%; Carbohydrates: 38-46%; Lipids: 4-8%

Dosage: Based on NRC requirements, no standard dosages

	Packaging:	25 kg bag
	MINPORK	
	Company/Manufacturer:	Zeus Biotech Limited, Karnataka, India http://www.zeusindia.net/minporkpro.html
	Description:	Micromineral-yeast complex of Mn proteinate, Cr proteinate, and Se proteinate
	Dosage:	150g/ton of feed
	Packaging:	25 kg bag
Se yeast	**ALKOSEL**	
	Company/Manufacturer:	Lallemand Animal Nutrition, Milwaukee, WI http://www.lallemand.com/ANAH/eng/alkosel.shtm
	Description:	An inactivated whole cell yeast (*S. cerevisiae*) product containing elevated levels of the essential trace elements and Se in its natural food form, L (+) selenomethionine.
	Dosage:	Piglet diet: 0.3 ppm (150 g/ton); fattening pig diet: 0.1 ppm (50 g/ton); sow diet: 0.2 ppm (100 g/ton)
	Packaging:	55 lb bag
	CEN-Se	
	Company/Manufacturer/Distributor:	Cenzone Tech Inc., San Marcos, CA http://www.cenzone.com/Eng/ENindex.html
	Description:	Contains microencapsulated Se from Se yeast. Predominantly in the form of L (+) selenomethionine.
	EXCEL HIGH SELENIUM	
	Company/Manufacturer:	Cypress Systems, Inc. http://www.cypsystems.com/product/excellHSY2000.html
	Description:	Produced from the introduction of Se salt during active, aseptic, aerobic fermentation. During fermentation the temperature, pH, and

	percentage growth are closely regulated to assure proper uptake of Se. This process produces primary grown high protein yeast that is fortified with a biologically bound mineral composition.
Packaging:	25 kg bag
LFA Se YEAST 2000	
Company/Manufacturer/Distributor:	Prince Agri Products, Inc., Quincy, IL. http://www.princeagri.com/productdetails.asp?id=2306
Description:	A primary product not made from byproducts and derived from pure culture of *S. cerevisiae*. It is grown on enriched purified cane and beet molasses under carefully controlled conditions. It contains 2,000 ppm Se with typical analysis of 99.5% organically bound Se and 75% or greater selenomethionine.
Dosage:	For use as a Se supplement in premix manufacturing only. Must be diluted to no more than 600 ppm Se before added to complete feed.
Packaging:	25 kg bag
ORGANIC SELENIUM YEAST	
Company/Manufacturer:	Ultratech Laboratories, Inc. http://www.ultrateck.net/yeasts.html
Description:	Food grade whole cell yeast of *S. cerevisiae* product containing controlled high levels of Se. The natural yeast fermentation process is supplemented with the necessary levels of Se. The yeast cream is pasteurized to prevent contamination and is spray dried for the highest quality and purity. This process allows the Se to interact with the yeast cell components. The gentle processing conditions cause a natural chelating effect that preserves the level of highly available essential nutrients.
Dosage:	50 to 200 g/metric ton of complete feed
Packaging:	225 g jar; 25 kg bag

SELENOSAC-E

Company/Manufacturer:	Jaysons Agritech Private Limited, India http://www.zeusindia.net/selenosac.html
Description:	Se-Cu yeast complex fortified with Vit. E
Composition:	Se: 2,000 ppm; Cu: 10,000 ppm; Vit. E: 10%
Dosage:	For poultry feed: 150 g/ton (breeder diet); 100 g/ton (broiler diet); 150g/ton (layer diet)
Packaging:	1 kg bag; 25 kg bag

SELENOSOURCE™AF 2000

Company/Manufacturer/Distributor:	Diamond V Mills, Cedar Rapids, IA http://www.diamondv.com/products/selenosource_af/profile2000.htm
Description:	A product of which the major component is selenomethionine. The material is spray dried and packaged. It is a quality, pasteurized high-Se yeast product (*S. cerevisiae*). Contains both Se yeast and dried yeast.
Analysis: (as fed basis)	CP: 48%; Crude fat: 0.6%; Crude fiber: 0.9%; Ca: 0.3%; P: 1.0%; Se: 2,000 ppm; Organic Se: 98% of total Se
Packaging:	55 lb bag

SELPLEX

Company/Manufacturer:	Alltech, Inc., Nicholasville, KY http://www.alltech.com/About/sel-Plex.htm
Description:	Se yeast product
Dosages:	0.3 ppm of complete feed
Packaging:	25 kg bag

Se YEAST

Company/Manufacturer:	Saf Agri-Lesaffre Group, Milwaukee, WI http://www.saf-agri.com/english/yeastmin.htm

	Description:	Se yeast is a *S. cerevisiae* yeast strain specially cultivated on a beet-molasses medium enriched with Se salts. It is inactivated by heat treatment and spray-drying.
	Analysis:	Se content: 1,600 ppm, 87% is intracellular Se; Protein: 47-53%; Carbohydrates: 32-40%; Lipids: 4-8%
	Dosage:	Based on NRC requirements, no standard dosages
	Packaging:	25 kg bag
	VETA-ORSEL	
	Company/Manufacturer:	Vetagri http://www.vetagri.ca/products.php?category_id=CAT007
	Description:	A source of Se yeast with added Vit. E (as alpha tocopherol acetate) and fermentation soluble products.
	Dosage:	100-200 g/ton (swine, poultry, prawn, and fish diets); 10 g/head/day (livestock diets)
	Packaging:	2 kg bag; 10 kg bag; 20 kg bag
	YEAST SELENIUM	
	Company/Manufacturer:	Angel Yeast Co. LTD-China http://www.angel.com.cn/tj/feed/Yeast%20Selenium%20(for%20Feed).pdf
	Description:	Yeast Se produced by replacing parts of sulfur-containing AA in the yeast with Se in the form of selenomethionine, selenocysteine, and selenocystine.
	Dosage:	300 g/ton
	Packaging:	10 kg bag
Zn yeast	**ORGANIC ZINC YEAST**	
	Company/Manufacturer:	Ultratech Laboratories, Inc. http://www.ultrateck.net/Ultrateck_Yeasts.pdf
	Description:	A spray dried whole cell yeast of *S. cerevisiae* containing controlled

		high levels of Zn. The yeast cream is then pasteurized to prevent contamination and spray dried for the highest quality and purity. This process allows the Zn to interact with the yeast cell components, and the gentle processing conditions cause a natural chelating effect that preserves the level of highly available essential nutrients.
	Dosage:	50-200 g/metric ton of complete feed
	Packaging:	225 g jar; 25 kg bag
	ZINC YEAST	
	Company/Manufacturer:	Saf Agri-Lesaffre Group, Milwaukee, WI http://www.saf-agri.com/english/yeastmin.htm
	Description:	Zn yeast is a *S. cerevisiae* yeast strain specially cultivated on a beet-molasses medium enriched with Zn salts. It is inactivated by heat treatment and spray dried.
	Analysis:	Zn content: 2,600 ppm, 70% is intracellular Zn; Protein: 41-53%; Carbohydrates: 35-43%; Lipids: 4-8%
	Dosage:	Based on NRC requirements, no standard dosages
	Packaging:	25 kg bag

Table 8. Yeast fractions

Yeast autolysates	**YEAST AUTOLYSATE DEHYDRATED**	
	Company/Manufacturer:	Ultratech Laboratories, Inc. http://www.ultrateck.net/Ultrateck_Yeasts.pdf
	Description:	Dried enzymatic digest of primary grown yeast produced from an unmodified strain of the botanical classification *Saccharomyces* using an autolysis process. Yeast autolysate is processed using a proven strain of *S. cerevisiae*. The finished product is brown in color with a yeast aroma and suitable for various poultry and livestock

		feed product applications.
	Packaging:	225 g jar; 25 kg bag
Yeast cell walls	**AGRIMOS**	
	Company/Manufacturer:	Lallemand Animal Nutrition http://www.lallemand.com/ANAH/eng/PDFs/AGRIMOS/AMOS20.FS.ENG.042002.pdf
	Description:	A specific combination of MOS and ß-glucans extracted from the yeast cell walls of *S. cerevisiae*. Obtained by the autolysis of yeast cells at high temperature and at a controlled pH. After yeast autolysis is completed, cell wall and yeast extracts are separated by centrifugation, and the cell wall fraction is spray dried.
	Analysis:	Dry extract: 94-99%; Protein: 12-22%; Carbohydrates: 42-56%; Lipids: 17-23%; Minerals: 5-8%
	Dosage:	Swine: 2 kg/ton (piglets); 1 kg/ton (fattening pigs)
	Packaging:	20 kg bag
	ALPHAMUNE G	
	Company/Manufacturer:	Alpharma Animal Health, UK http://www.thepigsite.com/BusinessDirectory/Focus.asp?Display=3029
	Description:	A unique combination of (1-3),(1-6) ß-glucans and MOS
	Analysis:	Moisture, max. 10%; Protein, max. 30%; total ß-glucan, min. 26%; total mannan, max. 30%
	Dosage:	500 g/ton of finished feeds in growing monogastric animals
	Packaging:	20 kg bag
	BIOGLUCAN	
	Company/Manufacturer/Distributor:	Cenzone Tech, Inc., San Marcos, CA http://www.cenzone.com/Eng/ENindex.html
	Description:	Contains cell wall extracts of β1,3-β1, 6-D-glucan and MOS derived

from the outer cell walls of *S. cerevisiae* yeast.

Dosage: 1-2 kg/ton of complete feed

Packaging: 25 kg bag

CITRISTIM

Company/Manufacturer: ADM Alliance Nutrition Swine
http://www.admani.com/allianceswine/CitriStim.htm

Description: A proprietary feed ingredient manufactured using a controlled fermentation process. A Candida yeast product is a source of MOS and β-glucan.

Packaging: 50 lb bag

FIBOSEL

Company/Manufacturer: Lallemand Animal Nutrition
http://www.lallemand.com/ANAH/eng/PDFs/FIBOSEL/FIB.FS.ENG.042002.pdf

Description: Cell fraction of a *S. cerevisiae* bakers yeast rich in carbohydrates mannan and ß-glucan.

Dosage: 100-150 g/ton (piglets); 50-100 g/ton (broilers); 500 g/ton (calves); 500-1,000 g/ton (aquaculture)

Packaging: 25 kg box

IMMUNE POLYSACCHARIDE

Company/Manufacturer: Angel Yeast Co., LTD - China
http://www.angel.com.cn/tj/feed.htm

SAFMANNAN®

Company/Manufacturer: Prince Agri Products, Quincy, IL
http://www.princeagri.com/productdetails.asp?id=2305

Description: Pure yeast cell wall material containing no carriers. It includes 19-20% mannans and 24-26% β-glucans.

	Dosage:	2-4 lb/ton of feed for swine
	Packaging:	25 kg bag
	YEAST CELL WALL	
	Company/Manufacturer:	Angel Yeast Co. LTD - China http://www.angel.com.cn/tj/feed/Yeast%20Cell%20Wall.pdf
	Description:	Product development involves atypical enzymolysis and natural potentiator addition by taking yeast and adopting advanced purification and refining techniques. This product is rich in β-glucan and functional oligosaccharides. It has increased heat stability, chemical stability, and tolerance against extreme processing conditions.
	Packaging:	20 kg bag
	Y-MOS	
	Company/Manufacturer:	Nutrex NV Belgium http://www.nutrex.be/products/feed/yeast_preparations/yeast_ymos.html
	Description:	Dried yeast cell walls, rich in ß-glucans and MOS
	Dosage:	0.5-2.0 kg/ton (pigs 6-22 kg); 0.5-2.0 kg/ton (sow lactation diet 10 days prior to farrowing); 0.5-2.0 kg/ton (poultry diets)
Yeast extracts	**CYPRESS EXCELL YEAST™**	
	Company/Manufacturer:	Cypress Systems, Inc. http://www.cypsystems.com/product/excellHSY2000.html
	Description:	A specifically selected strain of *S. cerevisiae* in which the yeast cell has been disrupted and enzymatically broken. This “cell breakage” dissolves the tough outer cell wall of the yeast and releases various internal components such as intercellular proteins, peptides, enzymes, and nucleic acid. Following downstream processing, the autolyzed yeast is recovered with rich growth media and spray dried

		to create a highly palatable inactive dry yeast powder.
	Packaging:	25 kg bag
	NUPRO	
	Company/Manufacturer:	Alltech, Inc., Lexington, KY http://www.alltech.com/About/aquaproducts.cfm
	Description:	Source of dietary protein derived from yeast extract. The medium brown powder is hygroscopic.
	Analysis:	CP, min. 47%
	Dosage:	2.5-5% of total diet (pig starter diet); 4% of total diet (aquaculture/shrimp diet)
	Packaging:	25 kg bag
Yeast glucomannan	**BETAMOS™**	
	Company/Manufacturer/Distributor:	Alpharma® Animal Health, Fort Lee, NJ http://www.alpharmaanimalhealth.co.uk/
	Description:	A nonsynthetic, nonantibiotic, and nondrug source of ß-glucan and protein that enhances flavor and feed intake. Contains yeast extract from *S. cerevisiae*.
	GLUCOMAN- P	
	Company/Manufacturer:	Jaysons Agritech Private Limited, India http://www.zeusindia.net/glucaman.html
	Description:	EGM oligosaccharides from yeast.
	Composition:	Glucomannan oligosaccharides
	Dosage:	500 g/ton of feed (piglet diet); 1 kg/ton of feed (grower/finisher pigs and sow diets); 500 g/ton of feed (poultry diet); 500 g/ton of feed (fish diet); 3 kg/ton of feed (shrimp diet)
	Packaging:	25 kg bag

MACROGARD

Company/Manufacturer: Immunocorp AS
http://www.macrogard.com/

Description: Based on a well-characterized and scientifically proven β-1,3/1,6-glucan. The products are extracted and purified from food grade bakers yeast by patented processes.

Dosage: 250 g/ton of feed

Packaging: 25 kg box

MICROBOND

Company/Manufacturer/Distributor: Cenzone Tech Inc., San Marcos, CA
http://www.cenzone.com/Eng/ENindex.html

Description: Contains Clinoptilolite, a natural zeolite that has undergone a patented purifying activation manufacturing process that extracts all nonclay fractions interfering with mycotoxin adsorption. Also contains glucomannan derived from the outer cell walls of *S. cerevisiae* yeast.

Dosage: 1-2 kg/ton of complete feed

Packaging: 25 kg bag

MTB-100 or MYCOSORB

Company/Manufacturer: Alltech, Inc., Nicholasville, KY
http://www.alltech.com/About/mycosorb.htm

Description: An EGM product derived from the cell wall of yeast (*S. cerevisiae* strain 1026)

Dosages: 1 kg/ton (swine diets)

Packaging: 25 kg bag

YEAST GLUCAN

Company/Manufacturer: ABAC Advanced Bioproducts
http://www.abac.ch/glucan.html

	Description:	Yeast glucan is preserved in its native and particulate form, providing a maximum efficiency for enhancing the immune system obtained from a natural organic raw material produced worldwide.
	YEAST GLUCOMANNAN	
	Company/Manufacturer:	ABAC Advanced Bioproducts http://www.abac.ch/mannoprotein.html
	Description:	This product is an activated yeast cell wall that allows for free accessibility of glucan and increased mannan protein solubility.
Yeast mannan	**BIOMOS**	
	Company/Manufacturer:	Alltech, Inc., Nicholasville, KY http://www.alltech.com/About/bio-Mos.htm
	Description:	A phosphorylated MOS product derived from the cell wall of yeast (*S. cerevisiae* strain 1026)
	Dosages:	Swine: 2 lb/ton (grower/finisher diets); 1 lb/ton (sow diet); 4 lb/ton (starter diet)
	Packaging:	25 kg bag
	CENMOS	
	Company/Manufacturer/Distributor:	Cenzone Tech Inc., San Marcos, CA http://www.cenzone.com/Eng/ENindex.html
	Description:	Contains MOS and β1,3- β1,6-D-glucan derived from the outer cell walls of *S. cerevisiae* yeast.
	Dosage:	1-2 kg/ton of complete feed
	Packaging:	25 kg bag
	CYPRESS EXCELL YEAST™	
	Company/Manufacturer:	Cypress Systems, Inc. http://www.cypsystems.com/product/excellHSY2000.html
	Description:	A MOS and β-glucan complex extracted from the cell wall of *S.*

cerevisiae. Soluble portions of the yeast cells are removed by gentle digestion while the remaining insoluble cell wall fraction is washed and spray dried.

Packaging: 25 kg bag

ECOMOS

Company/Manufacturer: Aqua-In-Tech-Inc.
http://www.aqua-in-tech.com/ecomos

Description: A mannan-based complex sugar produced from fermentation components and is a heat stable, nonhygroscopic product.

Dosage: 250-500 g/ton of feed

Packaging: 10 kg bag

FERM MOS

Company/Manufacturer: Canadian Bio-Systems Inc., Calgary, Alberta, Canada
http://www.canadianbio.com/products/feedadditives_fermmos.html

Description: A natural heat stable MOS and glucose fermentation product derived from dehydrated brewers yeast extracts.

Dosage: For use in all species at 0.5-2.0 kg/ton of complete feed.

Packaging: 25 kg bags

MOS 500

Company/Manufacturer: Kanzy Medipharm, Inc.
http://www.engormix.com/e_products464-946.htm

Description: A MOS product derived from *S. cerevisiae* yeast culture grown on a complex mixture of sugar. It also contains *S. cerevisiae* and *Bacilus subtilis* cell wall extracts, yeast fermentation solubles, α1,3- α,6-D-glucan, MOS, *Aspergillus oryzae* and *A. niger* fermentation extracts, and plant derived enzymes.

Dosage: 2 kg/ton (sow late gestation diet); 1 kg/ton (pig starter and grower, sow lactation and gestation diets); 500 g/ton (finishing boar diet)

	Packaging:	25 kg bag; 25 kg drum
	ULTRA MANNAN OLIGOSACCHARIDES	
	Company/Manufacturer:	Ultratech Laboratories, Inc. http://www.ultrateck.net/yeasts.html
	Description:	Naturally derived extract from the cell wall of *S. cerevisiae* with a MOS content of approximately 50% of the carbohydrate fraction.
	Dosage:	100-300 g/ton of complete feed
	Packaging:	225 g jar; 25 kg bag
	VETA- MANOL	
	Company/Manufacturer:	Vetagri Consulting, Inc., Brampton, Ontario, Canada http://www.vetagri.ca/products.php
	Description:	A naturally derived outer portion of the cell wall of yeast *S. cerevisiae*, containing phosphorylated MOS that is scientifically proven to be beneficial to livestock. The MOS content is approximately 50% of the carbohydrate fraction and contains fermentation solubles, *Aspergilus oryzae* and *Bacillus subtillis* fermentation extracts.
	Dosage:	100-300 g/ton (swine, poultry, prawns and fish diets)
	Packaging:	2 kg bag; 10 kg bag; 20 kg bag
Yeast nucleotides	**ASCOGEN**	
	Company/Manufacturer:	Chemoforma Ltd., Rheinstrasse 28–32 CH-4302, Augst, Switzerland http://www.chemoforma.com/ascogen.html
	Description:	Contains phosphate, sugar, and base (PSB) complexes from *S. cerevisiae* yeast.
	Dosage:	500 ppm
	NUCLEOFORCE®	

	Company/Manufacturer:	Bioiberica, Barcelona, Spain; offices in NJ, USA http://www.bioiberica.com/nutritionalcare/nucleoforce.htm
	Description:	A balanced free nucleotide concentrate obtained from desiccated yeast. Cream-colored powder with a characteristic odor and taste.
	Analysis:	Free nucleotide content: 26.4%
	Dosage:	May vary between 200-900 ppm depending on targeted species
	NUCLEOSAC	
	Company/Manufacturer:	Jaysons Agritech Private Limited, India http://www.zeusindia.net/nucleosac.html
	Description:	Consists of peptonucleotides: 42%
	Dosage:	1 kg/ton (swine diet); 500 g/ton (poultry diet); 2 kg/ton (shrimp diet)
	Packaging:	1 kg bag; 20 kg bag
	NUPRO	
	Company/Manufacturer:	Alltech, Inc., Lexington, KY http://www.alltech.com/About/aquaproducts.cfm
	Description:	Source of dietary nucleotides derived from yeast. The medium brown powder is hygroscopic.
	Analysis:	CP, min. 47%; total nucleic acid: 5.08%
	Dosage:	2.5-5.0% of complete feed (pig starter diet); 4% of complete feed (aquaculture/shrimp diets); 1-5% of complete feed (poultry, dairy, and beef diets)
	Packaging:	25 kg bag

Table 9. Other related yeast-based products

EXERX-LOX	***Company/Manufacturer:***	Premier Nutrition Technologies, Farwell, TX http://www.pntechnologies.com/Exer%20Lox.htm
	Description:	Formula consists of wheat germ technology, L-Glu, vit. E, *S. cerevisiae*, and FOS.

	Dosage:	1-3 oz/head/day as top dress to daily feed; start feeding animals prior to periods of stress for ideal results.
	Packaging:	20 lb bag
FASTRACK PREBIOTIC PACK	***Company/Manufacturer:***	Defazios http://defazios.tripod.com/id22.html
	Description:	Contains beneficial microorganisms, yeast culture, enzymes, and FOS to help maintain a healthy digestive tract.
	Dosage:	2.5-5.0 lb/ton of complete feed; 0.5-1.5 oz/head/day (top dress)
	Packaging:	5 lb bag
FLAV-R-IZED LEANIUM 20	***Distributor:***	Kent Feeds, Muscatine, IA http://www.kentfeeds.com/2729.pdf
	Description:	Contains chelated trace minerals (for improved bioavailability), biotin, folic acid, and pyridoxine (source of water soluble vitamins), irradiated dried yeast and yeast culture sources (blocks the colonization of pathogens, allowing microflora balance in the gastrointestinal tract), cheese whey, a quality milk protein (to improve palatability and pig performance), Appetein® (a source of immunoglobulins with excellent availability of AA), and Micro-Aid® (an aid in the control of manure and/or ammonia odor).
	Dosage:	Feed as the sole diet for show pigs (40 lb to market)
	Packaging:	50 lb bag

Existing patents for yeast-based products

Table 10. Yeast cultures

Publication	Inventors (Date of patent)	Patent number	Title and abstract
US20040175831A1	Thevelein et al. (Sept. 9, 2004)	0175831A1	**Strains "fil," stress-resistant under fermentation and/or growth conditions** The invention relates to new eukaryotic strains, preferably yeast strains, having the new fil phenotype (i.e., having the unexpected property of conserving good stress resistance in fermentation and/or growth phase, while conserving normal respiratory and fermentation metabolism on fermentable sugars such as glucose). It also relates to the process for obtaining such strains.
US4132597	Kvanta, E. (Jan. 2, 1979)	4,132,597	**Method for cultivation of bacteria** A method for cultivating fast-growing bacteria and their stable metabolites in order to reach optimal cultivating time is disclosed. This comprises introducing a volume of inoculum containing the bacterium sought to be cultivated and a quantity of nutriment containing a nitrogen source, growing factors, a carbon source, and a pH-stabilizer into a fermentor. The volume of inoculum in the fermentor is utilized as a production determinative factor and is determined according to the following equation: $a = V.multidot.n/2^t$ Where a = volume of inoculum (L); V = cultivating medium's total volume (L); n = bacterium strain's generation time (hrs.); and t = cultivating time (hrs.). The result is a grown cultivating medium that includes a mass of the desired bacterium.
US5879915	Loubiere et al. (Mar. 9, 1999)	5,879,915	**Method for the natural production of formic acid or formate**

			The subject of the invention involved the production of formic acid and/or formate starting from a culture medium containing a fermentable sugar of a bacterial strain having a deficiency in the transportation or the metabolism of at least one fermentable sugar, containing an active degradation pathway for the preceding sugar via pyruvate formate lyase, capable of converting the preceding sugar mainly into formic acid and/or formate even in the presence of a nonlimiting concentration of the said sugar. It also relates to a fermentation process by culture of the said strain with a view to the conversion of a fermentable sugar into formic acid or formate, as well as the culture media enriched with formic acid or formate obtained, and also an extraction/purification process of the formic acid in the form of one of its volatile esters, preferably ethyl formate.
US4794080	Mays et al. (Dec. 27, 1998)	4,794,080	**Microbial co-culture production of propionic acid** A simultaneous sequential anaerobic fermentation process for the *in vitro* production of propionic and acetic acids is disclosed. The process comprises employing an obligatory two-component co-culture that maintains a relatively constant ratio of species populations over multiple passages. A first co-culture component is a *Lactobacillus* or *Streptococcus* that homofermentatively converts the hexose to lactic acid. A second microorganism in the co-culture is a *Veillonella*, which is metabolically incapable of assimilating the hexose and converts the lactic acid product to propionic and acetic acid. The co-culture is inoculated into a nutrient growth feedstock such as whole whey or a clarified dairy whey lactose permeate that contains a metabolizable source of a hexose such as glucose, lactose or sucrose.

US4769254	Mays et al. (Sept. 6, 1988)	4,769,254	**Microbial production of polyfructose** A water-soluble levan having an average MW of about 10,000-40 million, preferably about 5-25 million and especially about 10-20 million, which stabilizes a bovine serum albumin colloid having an index (EAI) of about 3-100 determined according to the formula EAI = 2T/OC, wherein T = turbidity measured at 500 nm, C = weight of emulsified protein per unit volume of the aqueous phase, and O = volume fraction of a dispersed oil phase produced by fermenting a nutrient growth medium feedstock having a carbon source consisting essentially of an assimilable sugar selected from the group consisting of sucrose, raffinose, or a mixture thereof with a microorganism capable of converting at least 50% of the fructose value of the sugar to the said levan under nutrient growth conditions that enhance levan production while suppressing ethanol production. It is useful as a colloid stabilizing agent, particularly with foods, beverages, pharmaceuticals, dentifrices, and cosmetics.
US4346115	Clement et al. (Aug. 24, 1982)	4,346,115	**Fermentation of acid-containing doughs** Fermentation of acid-containing dough in bread-making is carried out with a bakers yeast in the form of compressed fresh yeast or dried yeast that has reduced inhibition to acid in the dough. The yeast is preferably prepared by selecting a strain of quick yeast (adapted to maltose and stable on conversion and drying) and cultivating the yeast by a process wherein during a last discontinuous cycle of multiplication of the yeast, a discontinuous flow of molasses is carried out by brief interruptions of flow.

Table 11. Nutritional yeasts

Publication	Inventors (Date of patent)	Patent number	Title and abstract
US6045834	Howes et al. (Apr. 4, 2000)	6,045,834	**Compositions and methods for removal of mycotoxins from animal feed** A method of removing mycotoxins from animal feeds is described whereby a combination of a modified yeast cell wall extract and mineral clay is fed to animals in amounts sufficient to inactivate mycotoxins present in the feed. The yeast cell wall extract/clay mixture may be mixed with feeds, incorporated directly into pelleted feeds, or fed directly to animals.
US6344221	J. W. Evans (Feb. 5, 2002)	6,344,221B1	**Compositions and methods for reduction of effects of endophyte-infected forages** A method of binding and inactivating ergot alkaloids from forages is described whereby a combination of a modified yeast cell wall extract and a mineral clay is fed to animals in amounts sufficient to inactivate alkaloids present in the forages. The yeast cell wall extract/clay mixture may be mixed with feeds, incorporated directly into pelleted feeds, or fed directly to animals.
US7048937	Dawson et al. (May 23, 2006)	7,048,937B2	**Methods and compositions for control of coccidiosis** Feeding yeast cell wall-containing compositions, including those compositions comprising MOS to animals exposed to or infected with coccidia, especially poultry exposed to pathogenic species of *Eimeria*, resulted in improved livestock performance and physical condition as compared with those animals that were not fed such compositions.
US6413736; US5922560; and US6015684	Jacobsen et al. (Jul. 2, 2002; Jul. 13, 1999; and Jan. 18, 2000, respectively)	6,413,736B1; 5,922,560; and 6,015,684, respectively	**Astaxanthin over-producing strains of *phaffia rhodozyma*, methods for their cultivation, and their use in animal feeds** *Phaffia rhodozyma* strains are described that produce greater than 3,000 ppm astaxanthin based on dry yeast solids when cultivated in a volume of nutrient medium of at least about 1,500 L and

			containing in excess of 4%, preferably in excess of 6%, dry yeast solids. These and other strains are cultivated by an improved fermentation method comprising extending the maturation phase of the fermentation by one or more various techniques including exposing the yeast cells to a low-intensity light, slow feeding the cells with a rapidly metabolized energy source (e.g. glucose) and replacing the rapidly metabolized energy source with a slowly metabolized energy source (e.g. glycerol). The cells of these strains are incorporated into animal feeds, particularly feeds for salmonid fish, to impart or enhance the red pigmentation of these animals and products made from these animals.
US5182208; and US5356809	Johnson et al. (Jan. 26, 1993; and Oct. 18, 1994, respectively)	5,182,208; and 5,356,809, respectively	**Processes for *in vivo* production of astaxanthin and *phaffia rhodozyma* yeast of enhanced astaxanthin content** An economical process for *in vivo* production of the pigment astaxanthin and particularly a process for enhancing astaxanthin content of cultures of microorganisms of genus *Phaffia*. The process comprising culturing a microorganism of genus *Phaffia* in a nutrient medium containing an antibiotic, a cytochrome B inhibitor, or a terpenoid synthetic pathway inhibitor, cultivating surviving pigment enhanced microorganisms, and harvesting the yeast.

Table 12. Other related yeast-based products

Publication	Inventors (Date of patent)	Patent number	Title and Abstract
US4328250	Clement et al. (May 4, 1982)	4,328,250	**Active dried bakers yeast** A dry yeast composition in particulate form containing at least 92% DM is prepared consisting of active dry bakers yeast capable of fermenting sweetened doughs containing more than 5% sugar and an emulsifying agent having an HLB value of between 3 and 11. The emulsifying agent is added to the yeast before drying and protects the yeast during drying.

US4370420	Clement et al. (Jan. 25, 1983)	4,370,420	**Preparation of dried bakers yeast** Active dried bakers yeast is prepared by selecting a yeast strain stable to drying, cultivating the yeast strain in several aerobic fermentation stages and selecting conditions for the last stage that produce a compressed yeast having preferred gas release characteristics, harvesting and carefully washing the yeast from the last stage to obtain compressed yeast having the preferred gas release characteristics, adding to the compressed yeast an emulsion of an emulsifying agent, dividing the resultant mixture into fine particles, and drying the particles by flash pneumatic conveyor drying and/or fluidized bed drying to obtain active dry yeast having greater than 92% DM content. The dry yeast has an activity almost equal to fresh yeast on nonsweetened dough or sweetened dough.
US20060110512A1	Blomme et al. (May 25, 2006)	0110512A1	**Yeast-cream-dosing device and method** The invention relates to a yeast cream-dosing device and method. According to the invention, the yeast cream is disposed in an interchangeable transport container that is located inside a refrigerating compartment, the aforementioned container being connected to an extraction opening by means of an outlet conduit that can be opened and closed by an opening/closing mechanism.
US6127142	Harboe et al. (Oct. 3, 2000)	6,127,142	**Microbially derived enzymes having enhanced milk clotting activity and method of producing same** A method of producing a milk clotting enzyme including the steps of (a) fermenting a strain of *Rhizomucor miehei* or *Aspergillus oryzae* to form a fermentation product having a glycosylated *Rhizomucor miehei* aspartic protease and other proteins, and (b) subjecting a quantity of the fermentation product to a deglycosylating treatment to form a coagulant preparation having an at least partly deglycosylated aspartic

			protease and the other proteins. The at least partly deglycosylated protease has a milk clotting activity that is at least 10% higher than a milk clotting activity of the glycosylated aspartic protease.
US6403351	Sinskey et al. (Jun. 11, 2002)	6,403,351B1	**Pyruvate carboxylase polypeptide from *Corynebacterium glutamicum*** The present invention concerns an anaplerotic enzyme from *Corynebacterium glutamicum* that replenishes oxaloacetate consumed during lysine and glutamic acid production in industrial fermentations. In particular, isolated nucleic acid molecules are provided encoding the pyruvate carboxylase protein. Pyruvate carboxylase polypeptides are also provided.
US6534315	Bauer et al. (Mar. 18, 2003)	6534315B1	**Yeast transformation cassette** The present invention relates to a DNA cassette intended for the transformation of yeast. This involves leaving no useless exogenous DNA but the gene(s) of interest comprising at least one negative dominant marker, two direct repeat sequences (DRS) which are nonexogenous and nonrecombinogenic with the genome of the host strain. These two DRS flanking the negative dominant marker and optionally at least one gene of interest containing the elements necessary for its expression in the host cell. The invention also relates to a method of integration of gene(s) of interest or inactivation of a gene in yeast and of transformation of yeast with the DNA cassette, as well as to the yeast strains obtained.
US7009045	Abbas et al. (Mar. 7, 2006)	7,009,045B2	**Transformation systems for flavinogenic yeast** This invention is directed to the transformation of the flavinogenic yeasts, *Pichia guilliermondii* and *Candida famata*, and mutants thereof, by electroporation (electrotransformation) and by spheroplast transformation. The invention is also directed to nucleic acid constructs such as vectors, plasmids,

			and ARS sequences that transform flavinogenic yeasts, and mutants thereof, at a high level and in a stable manner so as to result in stably transformed yeast host cells that express/produce recombinant products. This invention also is directed to flavinogenic yeasts, *Pichia guilliermondii* and *Candida famata*, and mutants and temperature sensitive mutants thereof, which produce or overproduce riboflavin.
US5741695	Loiez nee Hennette et al. (Apr. 21, 1998)	574,741,695	**Strains of bread-making yeast, a process for obtaining same and the corresponding fresh and dry new yeast** New broad spectrum strains of bread-making yeast having a high multiplication yield, good nitrogen assimilation, and preferably good resistance to drying characterized by the fact that they simultaneously have all the following enzymatic activities: (1) maltose-permease activity after growth of the yeast on glucose medium in the absence of maltose (Test T1): at least 9 units; (2) maltase activity after growth of the yeast on glucose medium in the absence of maltose (Test T2): at least 80 units; and (3) invertase activity (Test T3): less than 10 units and preferably more than 2 units.
US4396632	Clement et al. (Aug. 2, 1983)	4,396,632	**Strains of yeast for bread-making and novel strains of yeast thus prepared** A complete and reproducible process for producing novel strains of yeast comprises making a first screening test and at least one other screening test selected from a group of screening tests that do not resort to any measurement of gas release, selecting by means of the said first and at least one other said screening test the desired strains from a group of diploid strains prepared previously either by hybridization or by mutation of existing strains. The tests are as follows: (1) measuring the average multiplication coefficient of a given strain by following the optical density variation of a standard medium seeded by a

			suspension of cells obtained from this strain; (2) measuring in the same manner the average multiplication coefficient of the said strain but in the presence of an inhibitor acid added to the standard medium; (3) measuring the maltose adaptation of said strain in the presence of glucose by determining the amount of maltose subsisting in a standard medium after a known amount of glucose added to this medium has been completely consumed; (4) measuring the invertase content of said strain; and (5) measuring the latent time of said strain. The hybridization can consist of systematic haploid crossings derived from quick *S. cerevisiae* strains adapted to maltose and haploids derived from very slow strains not adapted to maltose, but well adapted to sweet doughs and sometimes also to acid doughs.
US4318929; and US4318930	Clement et al. (Mar. 9, 1982)	4,318,929; and 4,318,930, respectively	**Process for obtaining new strains of yeast for bread-making and novel strains of yeast thus prepared** A complete and reproducible process for producing novel strains of yeast, comprises making a first screening test and at least one other screening test selected from a group of screening tests which do not resort to any measurement of gas release. Selection by means of the said first and at least one other said screening test the desired strains from a group of diploid strains prepared previously either by hybridization, or by mutation of existing strains. The tests are as follows: (1) measuring the average multiplication coefficient of a given strain by following the optical density variation of a standard medium seeded by a suspension of cells obtained from this strain; (2) measuring in the same manner the average multiplication coefficient of the said strain but in the presence of an inhibitor acid added to the standard medium; (3) measuring the maltose adaptation of the said strain in the presence of glucose by determining the amount

	of maltose subsisting in a standard medium after a known amount of glucose added to this medium has been completely consumed; (4) measuring the invertase content of the said strain; and (5) measuring the latent time of the said strain. The hybridization can consist of systematic haploid crossings derived from quick *S. cerevisiae* strains adapted to maltose and haploids derived from very slow strains not adapted to maltose, but well adapted to sweet doughs and sometimes also to acid doughs.

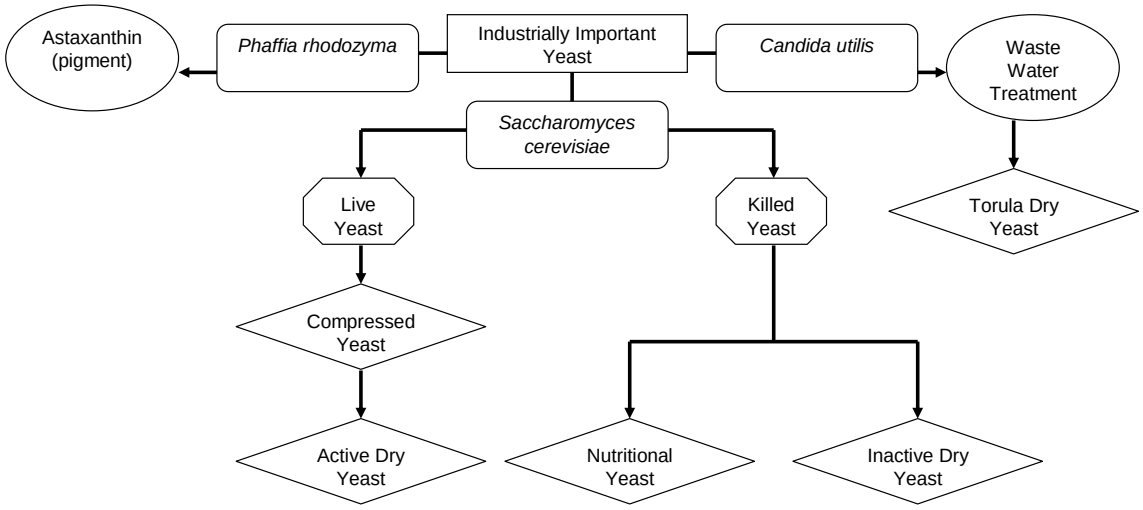

Figure 1. Industrially important yeast products: *Phaffia rhodozyma* produces an effective red pigmentor known as Astaxanthin. *Candida utilis* is grown on waste water known as sulfite liquor and utilizes pentose sugars from various industries to produce torula dry yeast. *Saccharomyces cerevisiae* has two subcategories, live and killed yeast. Live yeast refers to viable yeast cells that can be processed. By adding starch to live yeast cells, a compressed yeast is formed with a moisture content of approximately 70%. Drying compressed yeast to approximately 8% results in preserved yeast with a large concentration of yeast cells. Heat treatment of yeast at temperatures used for pasteurization produces killed yeast. Killed yeast that is ground and vitamin-enriched to meet specific nutritional requirements is referred to as nutritional yeast. Inactive dry yeast is a byproduct of the brewing industry with no fermenting ability.

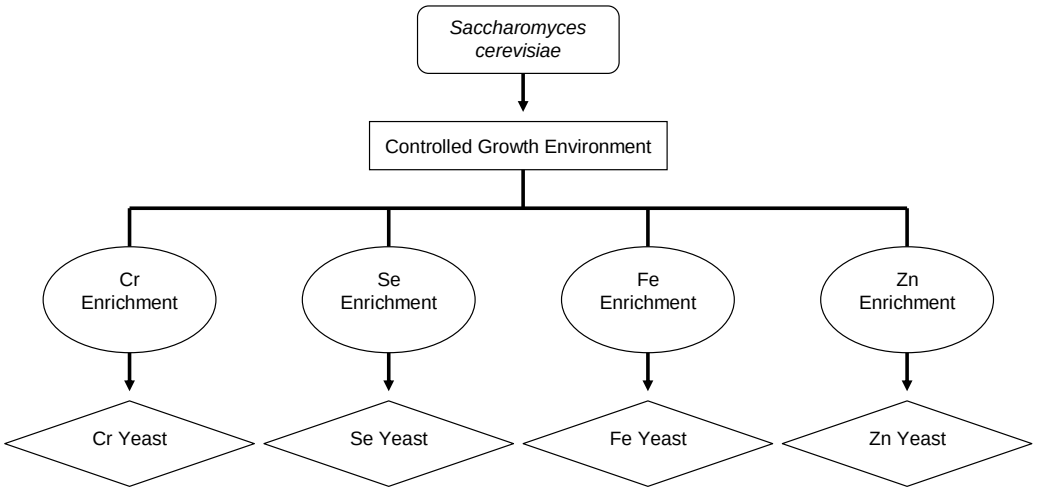

Figure 2. Yeast-based mineral products: a yeast inoculum, nutrient substrate, and a specific mineral (i.e., Cr, Se, Fe, and Zn) source are combined in an aerobic propagation system. As yeast growth occurs, the specific mineral is absorbed by the yeast cell and is incorporated into its organic matrix. During the concentration phase, nutrient media, pigments, excess water, and residual inorganic minerals are removed. The material is then spray dried and packaged.

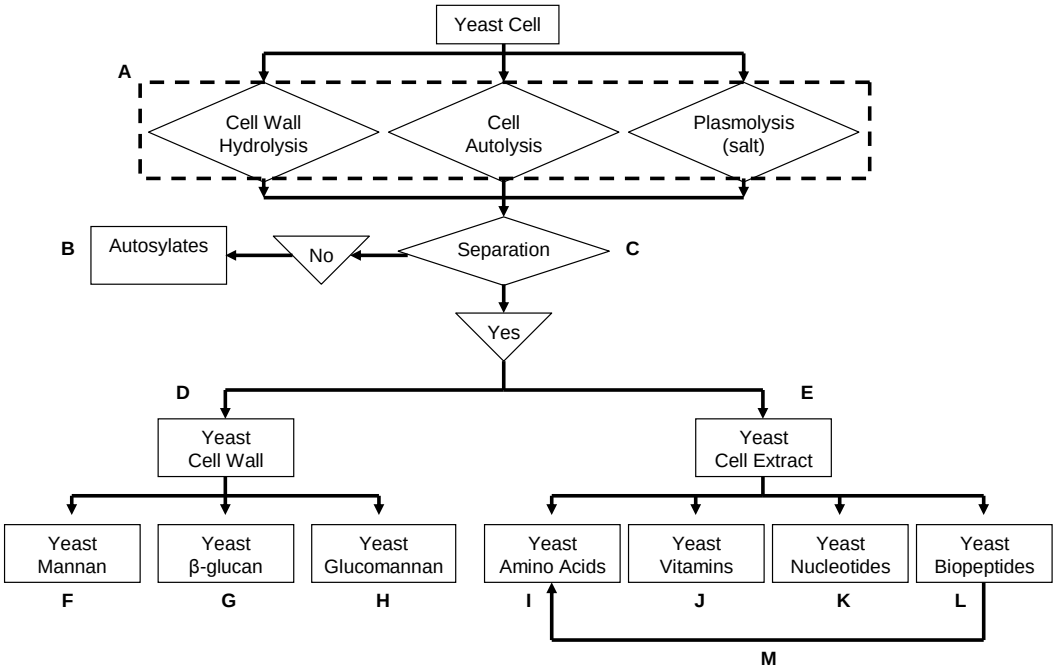

Figure 3: Yeast-based products: **A** = General classification of techniques for yeast cell lysis; **B** = Autosylate is a mixture of both cell wall and yeast components obtained by hydrolysis and subsequent drying and concentration of yeast without removing the cell wall. This product possesses the nutritional profile of yeast extracts and water holding capacity of the yeast cell wall. Often used when separation is cost prohibitive or unnecessary; **C** = Separation of the cell wall and yeast extract is done based on the desired product. Cell wall extraction conditions are naturally corrosive and may limit the utilization of yeast extract products; **D** = Isolation of the whole cell wall can be achieved by lysis and centrifugation of the autosylate. Further chemical or enzymatic digestion is required for isolation of individual components; **E** = Yeast cell extract isolation techniques are largely dependent on the component(s) of interest; **F** = Mannan may be isolated by heat treatment in alkali solutions; **G** = β-glucans are recovered following alkali treatment that removes the mannan; **H** = Glucomannan is recovered as the yeast cell wall is separated from the cell extract; **I** = Yeast is a source of AA such as Arg, Val, Trp, and Phe; **J** = Yeast contains water soluble vitamins including vit. B1 (i.e., thiamine), B2 (i.e., riboflavin), B3 (i.e., niacin), B5 (i.e., pantothenic acid), B6 (i.e., pyridoxine), B9 (i.e., folic acid), B12 (i.e., cobalamine), and H (i.e., biotin). Isolation of specific vitamins is possible; **K** = Yeast nucleotides have been used in research and for nutritional supplementation. Nucleotide extraction for solely for dietary supplementation may be cost prohibitive; **L**, **M** = Yeast cell extract contains biopeptides that may be enzymatically broken down to AA.