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Chapter

The Influence of *Candida* spp. in Intestinal Microbiota; Diet Therapy, the Emerging Conditions Related to *Candida* in Athletes and Elderly People

Alexandru Vasile Rusu, Berta Alvarez Penedo, Ann-Kristin Schwarze and Monica Trif

Abstract

The presence of *Candida* in the gut is normal, but an overproduction may lead to serious health problems due to an imbalanced gut, causing gut-related symptoms such as bowel movement changes, excessive gas, etc. Some diseases, such as Crohn's disease and ulcerative colitis, are associated with an overgrowth of *Candida* in the gastrointestinal tract. Several recent studies have shown that a prolonged candidiasis within the intestines is associated with *Candida* overgrowth syndrome or chronic fatigue syndrome. A healthy digestive system relies on a good balance of bacteria that live in the gut, and an important role in maintaining this balance is having the ingested type of food. *Candida* overgrowth can be prevented first of all by healthy eating patterns, as susceptibility is increased by a high-sugar diet and diabetes or nutritional deficiencies causing a dysregulated immune system. In general, *Candida*-associated conditions have a high impact on performance. Recent research has shown an increasing interest in the *Candida*-related conditions and diseases.

Keywords: physiology, gastrointestinal conditions, gut microbiota, elderly, athletes, diet therapy

1. Introduction

Everyone has yeasts like *Candida* spp., mostly Candida albicans, in their intestines, and only seriously ill people will get sick. In contrast, other therapists fear life-threatening diseases if these germs are detected [1].

Many patients are completely unsettled. These are very seriously ill patients such as cancer or AIDS patients whose defense is extremely weakened [2]. In their cases, the internal organs can fail due to a fungal attack. Fungal diseases and intestinal mycoses have actually increased in recent years. Gynecologists observe that more and more women suffer from vaginal mycoses.

The reasons for this increase are, for example, nutritional errors such as too much sugar and white flour products or nutritional deficiencies causing a dysregulated immune system [3]. However, treatments with cortisone and antibiotics and the increase in environmental pollutants are also contributing factors. All of these factors weaken our immune system and thus promote the spread of the fungi. If, for example, antibiotics have damaged the natural intestinal flora, *Candida* yeasts can spread because important physiological germs are lacking as opponents.

Unfortunately there are only nonspecific symptoms that can have many other causes. In the foreground are diarrhea and constipation—often alternating—flatulence, an abdominal distension, and abdominal pain. Affected people reported migraines, depression, liver diseases, and skin changes. But symptoms may or may not be due to *Candida*.

When referring to the intestinal yeasts, it is usually of *Candida* genus. Yeasts can be found practically everywhere in nature: they colonize the mucous membranes of humans and animals, adhere to objects, and can be found in water and soil. *C. albicans* are commonly found in the intestine. These yeasts were previously found in 80% of all intestinal yeast infections. In contrast to other *Candida* species, *C. albicans* adheres to the mucous membranes of warm-blooded humans and animals. Their transmission takes place directly through physical contact. In healthy people, however, this is completely unproblematic. But there are also numerous other types of *Candida* that have been on the rise recently. Yeasts find optimal living conditions in the intestine as the environment meets their requirements and provides them plenty of food [4].

People with weakened immune systems are particularly at risk of contracting *Candida*. Older people (elderly), whose defenses are weakening, are also considered a high-risk group [5].

The role of intestinal gut microbiota in health and disease is gaining more attention and is increasingly recognized [6]. The philosophy of alimentation might give us a clear start to see the patient as a whole again. It cannot only be drugs and medicine to treat the diseases [7].

2. *Candida* spp. as member of the human gastrointestinal tract microbiota

In the normal human gastrointestinal tract microbiota, *Candida* species are part of and can be found in the oropharynx, esophagus, gastrointestinal tract, and vagina. When the immune system is compromised from different reasons, a local or invasive infection can be developed [5, 8].

Candida species are among the most common yeast, and as fungi in stool cultures, the most common germ is *C. albicans*. *C. albicans* is one of the optionally pathogenic fungi that only trigger a disease under certain conditions [1, 9, 10]. However, numerous other types of fungi can also be detected in healthy intestinal flora in small numbers of germs using modern methods. With reduced immune defense like with HIV disease, but also with diabetes mellitus or cancer and with therapies with immune inhibitors (immunosuppressive therapy, e.g., with steroids [cortisone]), the amount of *Candida* in the intestine can increase significantly, so that a serious disease becomes possible [2].

Overgrowth of the intestine (over 1,000,000 fungi/g stool) is often accompanied by annoying gas, intestinal cramps, and/or diarrhea. If such symptoms occur in patients with a weakened immune system, overgrowth with *Candida* should also be considered [11–13].

3. *Candida* hypersensitivity syndrome

Candida hypersensitivity syndrome was first described 20 years ago. For many years, *C. albicans* has been mentioned as the cause of *Candida* hypersensitivity syndrome. This chronic syndrome is also known as chronic candidiasis, *Candida*-related complex, and "the yeast connection" [14].

A *Candida* "infection" or colonization—not proven—is associated with a variety of diseases, e.g., cancer, permanent fatigue and exhaustion, depression, and headache. In addition, there is always speculation that the irritable bowel may have to do with an overgrowth of fungi in the intestine. Still enough scientific evidence is lacking [15–17].

Candida is often held responsible for unspecific physical complaints or symptoms. As explained above, the simple detection of fungi in the intestinal flora in small numbers does not justify the start of a corresponding therapy [18]. Extensive and often costly treatment methods such as stool enema, colonic hydrotherapy, detoxification, and antifungal diets are particularly special or rejecting self-urine therapy as unscientific and unsuccessful [19].

Symptoms such as fatigue general malaise and genitourinary and neuropsychiatric complaints and nonspecific gastrointestinal symptoms are reported.

The syndrome is considered to be caused by vaginal and intestinal fungal overgrowth, production of fungal toxins, inflammation, and invasion of mucous membranes. In such conditions, the usual therapy will consist of a rigorous long-term antifungal treatment and "yeast elimination" diet [20–22].

A nutritional imbalance demonstrated by diet analysis could lead to the development of further nutritional deficiencies for a prolonged period of time diet [19, 23].

4. An overview of *Candida*-related conditions in athletes' case: impact on athlete physiological performance capacity

Exercise has a strong impact in an athlete's body. In fact, intense exercise, and particularly endurance exercise, requires an adaptive regulation of athletes' body in order to fulfill the new physiological and biochemical demands. Under these stimuli, the muscle adapts by improving its metabolic, mechanical, contractile, and neuromuscular functions [24]. Glycogen storage decreases, mitochondrial biogenesis increases, and the balance of electrolytes varies [25]. Moreover, in response to the higher demand of oxygen and nutrients by the muscle, cardiac output, ventilation, and gas exchange increase, which finally results in an increased vascular dilatation. Exercise increases the risk of dehydration as a result of the increment of body temperature. In order to compensate for and reestablish the homeostatic equilibrium, the amount of glucocorticoids and adrenaline release should be higher [26, 27]. Furthermore, blood flow decreases in the liver, pancreas, and kidneys where metabolism activity increases.

Exercise also damages the muscle and highly influences systemic inflammation, intestinal permeability, and an increase in oxidative stress as well as immune response, all of them being related with delayed onset muscle soreness (DOMS) [28].

DOMS is a muscle pain or discomfort that begins after unaccustomed or high-intensity exercise [29]. Usually the peak of the pain appears 1–3 days after exercise and can last for 5–7 days postexercise [30]. DOMS is recognized as one of the most frequent and recurrent forms of sport injury affecting both athletic (including elite athletes) and nonathletic population. Its prevalence is higher when exercise activity increases (e.g., beginning of sporting season) or when a new type of activity is introduced. Duration and intensity of exercise also influence DOMS. Thereby, intense exercise is related to higher degrees of DOMS, immune system suppression, inflammation, and oxidative stress, while low-to-moderate exercise is related with enhancing the immune system and healthy lifestyle. Despite its high incidence, the mechanisms of DOMS remain uncertain, and there are no specific treatment strategies. DOMS can negatively affect several factors of athletic performance such as muscular pain, reduced joint range of motion, power reduction, altered muscle sequencing and recruitment patterns, and muscular strength [29]. Additionally, DOMS affects athletic performance by increasing the risk of other muscle injuries but also by making athletes more prone to suffer from opportunistic infections such as candidiasis. This may be mainly because of the underlying state of chronic inflammation due to exercise, altered immune system, and oxidative stress. Actually, infectious diseases and particularly fungal infections [31] have been identified as the most common and important health problems in athletes [32], especially in contact sports. Some studies found that among wrestlers, skin infections are a common cause of training and match disruption, thus directly affecting athletic performance [31]. Also it has been determined that *C. albicans*, one of the most important causative agents of opportunistic infections, was responsible of those infections in 5% of the analyzed athletic population [9]. Therefore, it can be assumed that the alterations due to the impact of exercise (mainly increase of inflammation, affected immune system, and oxidative stress) may alter gut microbiota, increasing the risk of opportunistic infections such as *Candida* infections. Other studies found that in comparison with controls, athletes used twice as frequently oral antibiotics [33]. This supports the hypothesis that specific variations in gut microbiota may even be the starting point of different diseases development [34].

Diet and nutritional or dietary supplements have been identified as the main factor affecting gut microbiota (**Table 1**). In fact, it has been proven that dietetic changes can induce up to 57% of gut microbiota [35] variations in terms of composition and functioning in 24 hours [36, 37]. On the other hand, several studies have demonstrated the influence that gut microbiota have on essential processes affecting the individual's health and performance (e.g., immune response and metabolism of nutrients) [34, 38]. Therefore, it could be assumed that diet and food supplements (also called nutritional or dietary supplements) may be a critical factor through which gut microbiota can be modulated in order to benefit athletes in their performance. Actually a recent study has identified several dietetic patterns which address this idea [39].

Most studies analyzing the impact of probiotics in athletic performance highlight their positive impact on the immune function, gut mucosa permeability, and oxidative stress resulting from intense exercise but also they increase the risk of respiratory diseases that are very common in athletes [40]. Thus, probiotics have been proven to improve athletes' performance.

Up to now, there is no specific information on how diet and food supplements directly affect *Candida* and how *Candida* further impact athletic performance. However, interesting data shown may give a hint regarding *Candida* behavior with respect to probiotic consumption [41]. A study [41] evaluated healthy young individuals and analyzed the impact that probiotics consumption has on the presence of *Candida* in oral cavity. Results show 46% reduction in *Candida* prevalence after probiotics consumption in oral cavity. *C. albicans* was the main *Candida* spp. identified followed by *C. tropicalis* [42].

Finally, evidence supports that also antibiotics influence gut microbiota composition. The use of antibiotics increases the risk of opportunistic candidiasis

Nutrient	Dose	Effect
Carbohydrates	7–12 g/kg/day (endurance athletes)	A fatigue reduction and an improved performance and mood can be achieved during an intense training by consuming high doses of carbohydrates ad libitum
Proteins	1.2–1.6 g/kg/day (elite athletes)	The infection incidents increase due to a protein deficiency by decreasing the T cell functions which affect the immunity system
Fat	15–30% of the diet/day	A reduction of the intestinal inflammation, bacterial translocation, and gastrointestinal stress can be achieved by fat diets with good amount of omega-3 and omega-6 However, a high-fat diet may reduce the total gut microbiota
Fiber	38 g/day man 25 g/day women	Lower level gut microbiota is associated with low-fiber diet and low antipathogenic bacteria and therefore will be an increase in gut inflammation and less sympathetic nervous system stimulation However, gastrointestinal stress may be caused by a high-fiber diet
Probiotics	Highly variable depending on the strain, microbial composition, and metagenome Because of gut microbiota diversity in humans, there was not established a standard dose	Supplementing the diet with fermented food can stimulate the expansion of microorganism like *Bifidobacteria* (*B.*) and *Lactobacillus* (*L.*) that have beneficial metabolic functions. For example, improving short-chain fatty acids results in an increasing immune and barrier functions

Table 1.
Dietary modifications for the improvement of gut microbiota [39].

infections. Additionally, it has been also reported that antibiotics may cause fatigue and therefore negatively influence athletic performance [41]. Research done to analyze the relation between the total use of antibiotics (duration of antibiotic courses) and the degree of fatigue has shown that the longer the antibiotic courses, the higher the fatigue scores obtained [43, 44].

Lately studies evaluated the ergogenic effect of probiotic supplementation and their effect on physical exercises, trying to identify their mechanisms of action and on how could they influence the improvement of performance. Due to the fact that only few studies were performed and demonstrated the ergogenic effect of probiotics, further studies should investigate the subject for better understanding [45–52].

5. An overview of *Candida*-related conditions in elderly case: physiological alterations

The term "elderly" comprises those individuals aged 60 and older, and they represent the fastest growing population group. In fact, in 2017 the global population of 60 years old and over totaled 962 million, and it is foreseen to reach 2.1 billion by 2050 [53]. Already by 2030 it is anticipated that nearly 35% of the European population will be over 60 and 11% over 80 years [53]. With age progression, deficiencies of physiological functions occur, making elderly more vulnerable to diseases and infections, particularly from fungal species [54]. Genus *Candida* is considered the most important cause of opportunistic infections affecting especially immunocompromised patients and elderly people and the major causative agent of nosocomial infections [55]. The step from *Candida* colonization to subsequent infection is not yet clear. However it has been proven that the natural flora which develops within the gastrointestinal tract can represent the main source in the development of severe infections.

Candida infections are very difficult to diagnose in the elderly and have a complicated therapeutic management [56]. Signs and symptoms are often nonspecific and can vary depending on the area affected. Thus, diagnosis depends on the clinical evaluation supported by biochemical and microbiological analysis. Given the difficulty of diagnosing *Candida* infection, efforts have been focused on the development of new strategies and diagnosis methods such as new culture methods with increased sensitivity. Also novel antigen-based tests are available for the detection of mannan levels which is the main component of *Candida* cell wall and 1,3-β-D-glucan which is mainly used in critically ill patients as it has high sensitivity [54, 57]. Finally, real-time polymerase chain reaction technique is also applied for the detection of five different *Candida* spp. [54].

Regarding the epidemiology, 90% of all *Candida* infections are caused by *C. krusei*, *C. glabrata*, *C. albicans*, *C. tropicalis*, and *C. parapsilosis* [58].

Aging-related physiological changes and other factors frequently affecting the elderly such as comorbidities, polypharmacy, and high colonization rate result in an extremely high mortality rate (from 36 to 63%) [59].

The oral cavity is considered a major physiological importance and experiences numerous alterations with aging process. The impaired functioning of the salivary gland alters the quality and quantity of saliva (hyposalivation). This impacts the equilibrium of the resident oral microbiota and also results in the decrease of defensive proteins (such as salivary peroxidases or myeloperoxidase) as well as other substances with antimicrobial activity (e.g., lysozymes), facilitating the development of oral candidiasis. Using removable dental prostheses and their deficient hygienization also contribute to oral candidiasis. *C. albicans* followed by *C. glabrata* and *C. tropicalis* have been identified as the most prevalent *Candida* spp. found in dental prostheses [60]. The use of drugs that irritate or damage the oral mucosa, such as long-term antibiotic intake, as well as the presence of chronic and/or concurrent diseases may also lead to candidiasis. As already mentioned, *Candida* colonization can lead to severe infections. Thus, from oral cavity colonization, *Candida* may increase the colonization index and reach easier other areas such as the respiratory system [61].

Further, oral candidiasis may lead to appetite decline, and this can limit the nutrient intake which can directly influence gut microbiota growth. Appetite decline can also be a consequence of other age-related physiological alterations (**Table 2**) [62]. The impaired masticatory efficiency produced by poor dental health and related pain, loss of teeth and muscle bulk, and lower sensitivity (including taste, smell, and sight) have a negative influence on appetite as food remains uninteresting [62, 63]. Oropharyngeal and esophageal motility diminished the risk of swallowing impairments (e.g., dysphagia) and prevalence of gastroesophageal reflux. Additionally, alterations in the secretion and peripheral action of the hormones that regulate the wish to eat, hunger, and satiation can also reduce appetite. Besides the reduction of appetite, the nutritional status of the elderly can be influenced by the changes in gastrointestinal motility which can lead to reduced digestion and absorption, among others. All those result in the changes in the availability of nutrients in the gut which influence the abundance of *Candida* and may lead to dysbiosis. For example, it has been proven that a high-fat diet stimulated the increase in Firmicutes and Proteobacteria and a decrease in Bacteroidetes [64]. Poor nutrition has been also proven to be associated with the development of inflammatory pathologies (e.g. Crohn's disease) and chronic disease associated with

Natural aging physiological alterations
Alterations in oral cavity (e.g. hyposalivation and impaired masticatory efficiency)
Alterations in the secretion and peripheral action of the hormones that regulate the wish to eat, hunger, and satiation
Changes in gastrointestinal motility
Immunosenescence (alterations in immune system such as decreased phagocytosis and age-related involution of the thymus or altersinvolution)
Changes in gut microbiota
Altered metabolism of certain drugs
Decreased renal function
Decreased hepatic function

Table 2.
Natural aging physiological alterations.

nutritional status (e.g., diabetes mellitus and cardiovascular diseases). Finally, poor nutrition can also derive in malnutrition which is one of the key factors influencing the growth of gut microbiota and, thus, may also lead to the dysregulation of the immune system and posterior infection.

The immune system is also affected with aging (a process known as immunosenescence) [65]. Hence, there have been identified several altered immune parameters as well as adaptive and innate immunity influencing the development of chronic inflammatory status. Also the composition of gut microbiota varies with aging [66]. It decreases the number and variety of many protective commensal anaerobes such as lactobacilli and bifidobacteria. Beside this, phagocytosis is altered as a consequence of the functional insufficiency of monocytes and macrophages. On the other hand, "altersinvolution" (referring to age-related involution of the thymus) leads in a decline in circulating antigen-presenting cells (e.g., dendritic and T cells) [67]; T cells show altered cytokine production and lose their memory capacity as well as decrease the number of circulating B cells. Consequently, the immune system is compromised, and thus, there is a higher risk for the elderly to develop serious fungal infections, especially disseminated candidiasis. The source of this infection is often the gastrointestinal tract. The administration of broad-spectrum antimicrobial agents to these patients increases their risk of *Candida* infections by increasing the frequency and magnitude of gastrointestinal tract colonization by *Candida* spp.

Physiological changes associated with aging also affect the metabolism of many drugs [68]. As time passes, the hepatic capacity diminishes, affecting drug clearance. Specifically, the microsomal cytochrome P450-dependent monooxygenase system is altered, and therefore, the drugs that undergo this pathway cannot be cleaned properly. Liver volume and blood flow also decline, impacting drug clearance. In addition renal size and volume are reduced. There are less glomeruli and juxtamedullary nephrons, resulting in a decrease in filtration area of the glomerular basement membrane and decreased permeability. Thus, the glomerular filtration rate (GFR) is decreased [69]. Both liver and renal modifications impact the elderly's pharmacokinetics and pharmacodynamics variables, thus making them at higher risk of adverse drug reactions and harmful drug interactions. Together with the above information, other common factors such as serious underlying diseases and comorbidities, the use of antibiotics and immunosuppressive drugs, living in care facilities, or being hospitalized increase the risk of the elderly suffering from *Candida*-induced infections (particularly *Candida* oral infections) and make them more vulnerable.

For frail elderly, severe surgeries, the use of central venous catheter, and parenteral nutrition are associated with candidemia related to biofilm formation and hence persistent colonization and infections [70]. Biofilm formation by an irreversible adhesion of a community of microorganisms which attached to each other on a surface, inert material, or living tissue, produce extracellular polymers that provide a structural matrix. The microorganism in this community behaves differently, showing more resistance to antibiotics and lower growth rates. Different *Candida* spp. have been identified to be implicated in biofilm formation. Each of them exhibits particularities in terms of biofilm formations (morphology, extracellular matrix, antifungal resistance, etc.) and thus complicating treatment. *C. parapsilosis* has been characterized as the most frequently causative agent of catheter-related infections through biofilm formation [71]. It is an exogenous pathogen found mostly on the skin of healthy hosts which easily spread through hand contamination in hospitals and care facilities. *C. tropicalis* is particularly relevant in urinary tract infections [72, 73].

6. *Candida* elimination diet therapy

An important point is the amount of fungi found in the intestine. Antibiotic treatments are damaging the natural intestinal flora, and fungi such as *Candida* spread because important physiological germs are lacking as opponents [74]. Treatments such as antibody therapies or enteral nutrition can reduce the inflammation, and gut microbiota is improved.

A dietary formula for 1 week lacking fiber reduced the populations of fungi [75]. Therefore, it is believed that the gastrointestinal environment can be restored by a proper defined nutrition diet formula [76–78].

Such diets are high in sugar and total carbohydrates which are correlated with increased methanogen *Methanobrevibacter* and fungus *Candida* and other genera from different domains of life that are negatively associated with the consumption of fatty acids, protein, and amino acids [79].

Candida is the predominant fungal species capable of colonizing the gut and can vary extensively in time in response to recent carbohydrate consumption, antibiotic use, and environmental sources. Bacterial population structure primarily associates with long-term diet [80]. In a recent study, *Candida* correlated positively with long-term intake of total carbohydrates and sugar and had a strong association with recent carbohydrate intake.

Short-chain fatty acids (SCFAs) have been shown to exert fungistatic effect. Anaerobic intestinal microbiota, such as lactic acid bacteria (LAB) as a member of normal flora, produces from dietary fibers via fermentation of beneficial metabolites, and the major end products are SCFAs. Not only for the intestinal microbiota, SCFAs represent an energy substrate but for host cells as well. Their important role in reducing the development of gastrointestinal disorders, among others, is well-known, preventing overgrowth of *Candida* [81].

The probiotic strain *L. rhamnosus* GG offers benefit human health, and is a commonly used probiotic strain with immunomodulatory effect and bears an exopolysaccharide interfering with *Candida* growth and invasion tested in a model of gastrointestinal candidiasis, mostly attributed to *C. albicans* [82]. SCFAs have an effect on morphogenesis and therefore may provide a mechanism by which LAB could prevent candidal colonization. The growth rates are crucial for fungal growth in medium containing the disaccharide maltose as a sole nutrient source [74, 81].

In a clinical study performed in individuals with chronic intestinal *Candida* overgrowth receiving nystatin alone and following a diet therapy (avoiding foods high in simple sugars and starch), different cured rates have been achieved during the 3 months of tests, 42% compared to 85% [21].

The yeasts metabolize a part of the carbohydrates from food, producing carbon dioxide and fusel alcohols. The gas causes an abdominal distension, bloating, and abdominal pain. Prolonged exposure to fusel alcohols for weeks and months can damage the liver. It was only this spring that a special toxin produced by the *Candida* yeast was found, which is responsible for many of the effects on other parts of the body. There is still a lot of research to be done in this area.

Most of the usual antifungal diets are based on the elimination of sugar and other carbohydrates and can actually relieve bloating and other irritable bowel symptoms in some patients (with or without fungal overgrowth) [83, 84]. Practitioners of alternative medicine often claim that candidiasis—the most common cause of yeast infections (vaginal candidiasis) and oral thrush (oral candidiasis)—can be treated or prevented with diet and food supplements [11]. Despite a lack of clinical evidence, *Candida* diets have become incredibly popular in recent years, mostly among women with recurrent yeast infections.

The effect is probably based on a combination of different changes at the level of bacterial flora, the formation and transport mechanisms of intestinal gas, and the osmotic properties of the intestinal contents. The concept of the *Candida* diet is that *Candida* uses sugar compounds (carbohydrates) to extract energy from them. If these sugar compounds are no longer available through the diet, the *Candida* can be "starved" in this way [85].

The *Candida* yeasts break down carbohydrates from food into carbon dioxide and fusel alcohols. The gas causes a bloated stomach, a feeling of fullness, and pain in the intestinal area. If the exposure to fusel alcohols lasts longer, they can damage the liver. The *Candida* yeast produces a special toxin that has only recently been identified and can trigger symptoms such as migraines or joint illnesses [86].

A consistent antifungal diet of at least 5–6 weeks is also essential. It is important to deprive the yeast of their base food. Sugar, sweets, white flour products, and alcohol should be strictly avoided. Sweet fruit should also be avoided in the first 4 weeks. The focus is on a wholesome diet with lots of lettuce, vegetables, and whole grain products. The high-fiber diet not only strengthens the immune system but also presumably exerts a mechanical cleaning effect by sweeping the fungal nests out of the villi through its fibrous structure and at the same time stimulating the bowel movement [87, 88]. High-content phytochemicals with an antimicrobial effect make the whole-food diet the ideal antifungal diet—however, success is only permanent if there is a consequent change in diet.

Whole foods are the best way to prevent yeast infections. The yeasts will not find the right breeding ground in the organism of a healthy person. If there is already an infection, targeted therapy and a long-term change in eating habits to a healthy, natural diet are effective remedies.

In microbiological therapy, the focus is on strengthening the immune system [89]. Bacteria are extremely important for an intact immune system. An estimated 100 trillion bacteria live in the intestine, many of which are not yet known. It is now known that these bacteria have important functions for the immune system and are not simply there by accident. Experience after lengthy antibiotic administration speaks about, again and again, weaknesses in the body's defenses which are observed because these active ingredients not only destroy unwanted but also desired bacteria. In our environment, which is enlivened by countless germs, the animals die of fatal infections after a few days because their defense system is practically inadequate. The contact with bacteria is very important for the development of the immune system. This effect is mimicked with microbiological therapy. The patients are given probiotics and auto-vaccines for 3–6 months. Probiotics are preparations from intestinal germs that regulate the immune system. Several studies suggested that certain *Lactobacillus* probiotic strains enhance the effect of antifungal drugs (like fluconazole) used to treat yeast infections. However, there was no evidence that the strains could achieve the same effect on their own [90–95].

The use of probiotics in treating yeast infections is controversial. Although probiotics work by increasing bacteria beneficial to the vagina and gastrointestinal tract, their ability to prevent or treat candidiasis is a subject to debate. While many studies suggest that a daily probiotic can "slightly improve" imbalances that lead to yeast infections, others do not [96].

With these foods too, some of the bacteria will certainly live in the intestine. It is probably not possible to permanently colonize these bacteria in the intestine. However, a distinction must be made between probiotic medication and food. Special foods, such as yogurt preparations, cannot be used to inject as many bacteria as with medication. Patients would have to eat tons of yogurts in order to achieve a therapeutically effective number of bacteria. Then, however, they would have problems with the masses of animal protein again.

To permanently eliminate the yeast, a change in eating habits is crucial. The yeast must be deprived of their food base. It is very important to avoid sugar. In the acute diet phase of 4 weeks, patients even have to do without sweet fruits because *Candida* can also utilize fructose. Only sour apples, lemons, and grapefruit are allowed. The focus is on a high-fiber diet, which means a lot of salad and vegetables as well as whole grains [97, 98]. Their fiber exerts a mechanical "cleaning effect" by sweeping out the fungal nests between the villi, and they stimulate the movement of the intestine. In addition, fiber is cheap because it cannot be broken down by the yeast in the intestine. We therefore recommend our patients to eat whole foods.

The complex carbohydrates and especially the fiber are digested in the lower intestinal sections. However, the yeasts mainly colonize the upper sections because they require oxygen. Only relatively few yeasts can survive in the colon. Only an insignificant part of the yeast uses the complex carbohydrates and fiber [99].

The die-off effects (*Candida* dies) can be strong, especially at the beginning of treatment when a large amount of *Candida* fungi dies at once. Likely massive adrenal fatigue can be experienced during this period. In this case, the recommendation is to take a couple of weeks off not to add any new foods to diet. Die-off is usually a problem from the beginning to about the middle of treatment. As healing progresses, the die-off symptoms (like the other *Candida* symptoms) will occur less frequently and at greater intervals. Therefore, at the same time with the diet, it is highly recommended to start with antifungals and probiotics. The combination of these two kills the *Candida* yeast in the intestine and immediately populates it with "good bacteria."

An antifungal diet always represents an individual nutritional concept, which in general is based on the results of laboratory analysis. In the case of a stronger fungal attack, an antifungal medication is recommended. The microbiological therapy is often useful, since the intestinal flora is usually affected; otherwise the fungi would not have been able to multiply.

Candidiasis affecting the whole organism is fatal in about 70% of cases. The problem is *Candida*-induced sepsis, in which the pathogens can be found in large numbers in the blood. Around 40,000 people in Germany are affected by this invasive *Candida* infection every year. When it comes to hospital infections, it represents number 4 on the list of the most dangerous pathogens [100].

7. Conclusions

Numerous microorganisms live in our intestines, especially *Candida*. As long as the intestinal flora is in natural balance, *Candida* does not cause problems.

In people whose immune systems are weakened by disease or medication—the elderly population, *C. albicans* can also cause inflammation. The problem is that a *Candida* infection is often diagnosed late because of its diverse symptoms.

The *Candida* diet is believed to limit *Candida* colonization and thus prevent such opportunistic infections. The *Candida* diet's aim and scope are boosting the immunity, reducing inflammation, and improving gut health. The diet is based on removing added sugars, focusing on consumption of fermented foods, and avoiding pro-inflammatory triggers. By providing an optimal nutrition, a reduction of inflammation and depriving *C. albicans* will be possible. Antifungal diet is believed to greatly reduce the number of microorganisms in the intestine within at least 4 weeks.

Nevertheless, it is recommended to carry out the diet under medical supervision, especially if there are problems with the intestinal flora.

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Conflict of interest

The authors declare no conflict of interest.

Author details

Alexandru Vasile Rusu[1]*, Berta Alvarez Penedo[1], Ann-Kristin Schwarze[1] and Monica Trif[2]*

1 Biozoon Food Innovations GmbH, Bremerhaven, Germany

2 Centre for Innovative Process Engineering GmbH, Stuhr, Germany

*Address all correspondence to: rusu@biozoon.de and monica_trif@hotmail.com

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