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Targeting Candida-driven gut dysbiosis with probiotics: A novel approach to mitigating depression in cancer patients

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ABSTRACT

Depression in cancer patients remains a significant challenge, with multifactorial origins encompassing psychological, biological, and social determinants. Recent research has highlighted the role of the gut microbiome, particularly fungal dysbiosis driven by Candida overgrowth, as a contributor to inflammation and neuropsychiatric symptoms in oncology. The present hypothesis proposes that targeted probiotic supplementation could mitigate Candida-driven dysbiosis, reduce systemic and neuroinflammation, and thereby alleviate depressive symptoms in cancer patients. This manuscript reviews the existing evidence for the gut-brain-immune axis in cancer-related depression, distinguishes the unique role of Candida among gut microbiota alterations, evaluates current antifungal and probiotic interventions, discusses safety considerations in immunocompromised populations, and outlines research pathways for clinical translation, including candidate probiotic strains and the use of biomarkers for personalized therapy. Rigorous clinical trials are required to validate efficacy, safety, and optimal implementation strategies. If proven, microbiome-targeted approaches could complement current standards, addressing the complex biopsychosocial needs of cancer patients.

Keywords: probiotics, depression, neoplasms, candidiasis, therapeutics

INTRODUCTION

Depression affects approximately one-third of individuals living with cancer, significantly impacting quality of life and prognosis [1]. While psychological and social stressors are traditionally emphasized, there is increasing recognition of biological contributors–including immune dysregulation and disturbances in the gut microbiome–that shape the onset and persistence of depressive symptoms in these patients [2, 3]. The concept of the gut-brain axis, whereby bidirectional signaling between intestinal microbiota and the central nervous system modulates mood and behavior, has gained traction, with bacterial dysbiosis and increased intestinal permeability ("leaky gut") implicated in a range of neuropsychiatric disorders [4-7]. Importantly, while previous hypotheses regarding probiotics and depression have focused largely on bacterial constituents and have been studied in non-cancer populations [8], cancer patients present unique vulnerabilities; cytotoxic therapies, antibiotics, and immunosuppression dramatically alter the gut ecosystem, increasing susceptibility to fungal overgrowth, particularly by Candida species [9, 10].

Candida, a common commensal fungus, can become pathogenic in the context of immune suppression, chemotherapy, or antibiotic-induced dysbiosis [9-12]. Unlike bacterial imbalances, Candida overgrowth is uniquely associated with marked increases in gut permeability, translocation of fungal metabolites (such as acetaldehyde), and potent activation of mucosal and systemic immune responses [13-15]. This can lead to the release of pro-inflammatory cytokines (interleukin [IL]-6, tumor necrosis factor alpha [TNF-α], IL-1β) and oxidative stress, which have been mechanistically linked to neuroinflammation, altered neurotransmitter metabolism, and depressive symptomatology [11, 12, 16-22]. Notably, acetaldehyde–a byproduct of Candida metabolism–causes DNA damage and oxidative stress, which further contribute to neuropsychiatric complications (see **Figure 1**) [23-25]. While inflammation is a recognized driver of depression in cancer [26], Candida overgrowth represents a particularly critical and underexplored contributor, distinct from other microbiota alterations due to its robust immunostimulatory and neurotoxic potential [22, 27]. Nevertheless, it is vital to acknowledge that inflammation is multifactorial in cancer, with bacterial dysbiosis, tumor biology, and treatment effects also playing significant roles [26, 28].

Despite the growing evidence for fungal influences on mental health, current clinical strategies for depression in cancer patients rarely address underlying mycobiome disturbances. Antifungal therapies are typically reserved for overt infections and are not tailored to subclinical or chronic Candida overgrowth associated with mood symptoms [29, 30]. Similarly, widely used antidepressants may have diminished

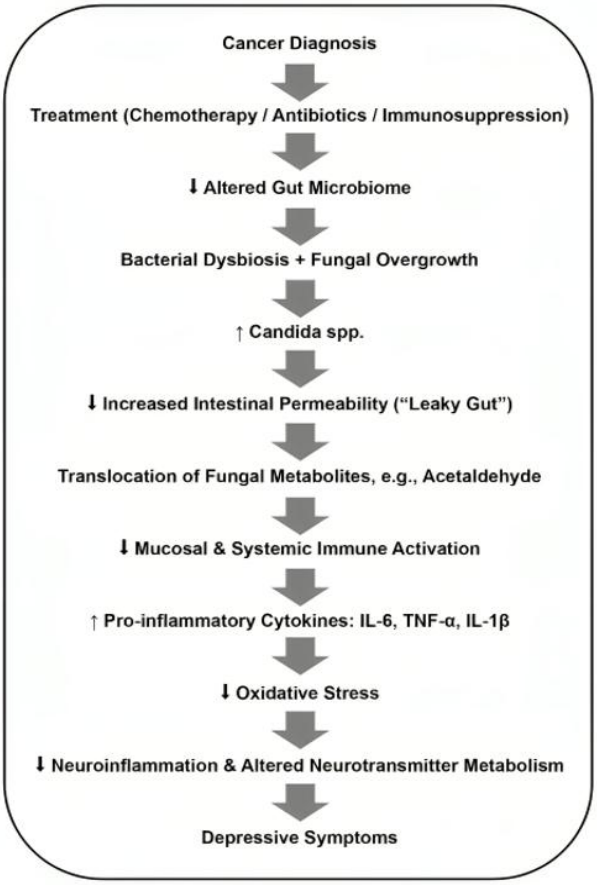

Figure 1. The hypothetical pathway and mechanism by which Candida overgrowth contributes to depression in cancer patients [9-25]

efficacy where inflammation or neurotransmitter disruption is pronounced [11, 12]. These gaps underscore the need for integrative approaches that address both biological and psychological domains, leveraging advances in microbiome science to inform adjunctive therapies. Nevertheless, it must be emphasized that, to date, no direct clinical studies have assessed whether probiotic supplementation reduces depressive symptoms via antifungal mechanisms specifically in cancer patients with documented candidiasis. The present hypothesis is therefore primarily inferential, based on preclinical findings and indirect evidence from non-cancer or non-fungal depression studies.

THE HYPOTHESIS

The hypothesis advanced herein posits that probiotic supplementation–specifically with strains capable of antagonizing Candida, restoring microbial balance, and exerting anti-inflammatory effects–could attenuate depression in cancer patients with evidence of Candida overgrowth. This builds on a growing literature linking gut dysbiosis to psychiatric symptoms but distinguishes itself by focusing on the unique pathophysiological mechanisms of fungal (rather than solely bacterial) imbalance in the oncology setting [3-8, 13, 27]. Probiotics, defined as live microorganisms conferring health benefits when administered in adequate amounts, may modulate immune responses, enhance gut barrier integrity, and produce neuroactive metabolites that influence central mood regulation [8, 31-34]. Notably, certain probiotic strains, such as Lactobacillus species (e.g., Lactobacillus plantarum, Lactobacillus acidophilus, Lactobacillus reuteri, Lactobacillus fermentum, and Lactobacillus casei) and probiotic yeasts (e.g., Saccharomyces boulardii, Saccharomyces cerevisiae, and Issatchenkia occidentalis), have demonstrated anti-Candida activity both in vitro and in animal models. Additionally, these probiotics have been shown to exert beneficial effects on mood and inflammation (see **Table 1** and **Table 2**) [13, 33-36]. However, the optimal strain(s), dosing, and formulation remain to be established for this specific population.

Table 1. Summarizing probable anticandidal properties of lactobacilli, which can be divided into direct and indirect effects [35]

Mechanism	Type	Molecule/process	Mode of action/effect	Details/examples
Bacteriocins & BLS	Direct	Plantaricin (Lactobacillus plantarum), BLS	Disrupts cell membrane integrity, depolarizes membrane, causes ion leakage and ROS, induces apoptosis	Only a few bacteriocins (e.g., plantaricin) studied in detail; membrane permeabilization, ROS ↑
Organic acids	Direct	Lactic, acetic, benzoic, sorbic acids	Acidifies environment, ATP depletion, membrane disruption, inhibits glycolysis; intracellular acidification	Benzoic acid impairs glucose fermentation; pH-dependent effects; turgor ↑, oxidative stress ↑
Fatty acids	Direct	SCFA, LCFA	Disrupts fungal membrane, increases fluidity/permeability, inhibits ergosterol synthesis, detergent-like action	Chain length may affect potency; causes loss of cellular electrolytes/proteins, structure damage
Reuterin	Direct	3-hydroxypropionaldehyde (glycerol-deriv)	Induces oxidative stress via thiol group interaction, growth inhibition, OxyR-mediated stress response	Inhibits various Candida spp.; aldehyde group is reactive
Biosurfactants	Direct	Glycolipopeptides, others	Prevents adhesion to surfaces/tissues, reduces cell wall charge, direct antimycotic activity	Lactobacillus pentosus biosurfactants; mechanism partially unknown
Enzymes	Direct	Chitinase-like proteins (Lactobacillus johnsonii)	Hydrolyzes chitin in cell wall, leading to cell wall degradation and fungal growth inhibition	Especially active against C. glabrata
Surface molecules (EPS)	Direct	Exopolysaccharides (e.g., LGG)	Reduces hyphal transition, decreases adhesion to epithelial cells	Cell wall-associated; mechanism not fully clear
Biological competition	Indirect	Mucin binding, exclusion, displacement	Outcompetes Candida for mucosal binding sites, reduces fungal adhesion and biofilm formation	EPS aids lactobacilli adhesion; supernatants reduce Candida adhesion to HeLa cells
Induction of antimicrobial peptides	Indirect	β-defensins, protegrins	Stimulates epithelial production of AMPs, which damage or permeabilize fungal cell wall/membrane	β-defensin 2/3 upregulated by Lactobacillus crispatus; synergistic with lysozyme/lactoferrin

Table 1 (Continued). Summarizing probable anticandidal properties of lactobacilli, which can be divided into direct and indirect effects [35]

Mechanism	Type	Molecule/process	Mode of action/effect	Details/examples
Immunomodulation	Indirect	MAMPs (Msa, p40, p75, SlpA, PGN)	Activates host immune responses (TLRs, NLRs), modulates cytokine profiles, enhances antifungal defense	Downregulates proinflammatory cytokines (TNF-α, IL-1β, IL-6, IL-17); upregulates IL-10, IL-22
Immune cell activation	Indirect	T/B cells, macrophages, dendritic cells	Activates/attracts immune cells, enhances antibody responses (IgG, IgM), modulates T cell balance	Induces protective IgG/IgM; modulates via TLRs; Lactobacillus acidophilus stimulates macrophage migration
Mucosal barrier protection	Indirect	Mucin (MUC2, MUC3) & tight junction proteins	Increases mucin secretion, upregulates tight junctions (claudin-1, occludin, ZO-1), maintains epithelial integrity	Protects against pathogen invasion and inflammation; Lactobacillus reuteri, Lactobacillus plantarum, Lactobacillus rhamnosus studied
Anti-inflammatory properties	Indirect	Cytokine modulation, tryptophan metabolites	Reduces inflammation, preserves barrier, balances immune response, increases anti-inflammatory cytokines	Tryptophan catabolism → indole derivatives → IL-22 induction (barrier/AMPs)
Biotransformation of host compounds	Indirect	Casein-derived peptides, others	Converts host macromolecules into antifungal secondary metabolites	Recently described casein-derived peptide with antifungal activity

Note. BLS: Bacteriocin-like substances; ROS: Reactive oxygen species; ATP: Adenosine triphosphate; SCFA: Short-chain fatty acids; LCFA: Long-chain fatty acids; BLS: Bacteriocin-like substances; EPS: Exopolysaccharides; LGG: Lactobacillus rhamnosus GG; PGN: Peptidoglycan; Msa: Mannose-specific adhesin; SlpA: Surface-layer protein; ZO-1: Zonula occludens-1; MUC: Mucin; AMPs: Antimicrobial peptides; MAMPs: Microorganism-associated molecular patterns; & TLR/NLR: Toll-like/NOD-like receptors

Table 2. Summarizing the potential anticandidal properties of probiotic yeasts [36]

Probiotic yeast strain	Targeted Candida species or virulence factors	Anticandidal mechanisms	Experimental/ clinical evidence
Saccharomyces boulardii	Candida albicans, Candida tropicalis, Candida krusei, Candida parapsilosis, Candida glabrata, Candida auris	Inhibits adhesion, biofilm formation, and filamentation; secretes small bioactive molecules; reduces inflammatory cytokines (TNF-α, INF-γ) in colon epithelial cells; prevents Candida albicans translocation in GI tract	In vitro, ex vivo, in vivo, and clinical studies
Saccharomyces cerevisiae	Candida albicans and non-albicans species	Inhibits adhesion, colonization, biofilm formation, filamentation; co-aggregation with Candida inhibits epithelial adhesion; Forms barrier on biotic surfaces; reduces virulence gene expression in Candida albicans; secretes bioactive molecules; decreases TNF-α, enhances IL-10 in host; reduces colonization and host cell damage; β-glucan decreases intestinal inflammation	In vitro, ex vivo, in vivo models
Issatchenkia occidentalis	Candida albicans, Candida tropicalis, Candida krusei, Candida parapsilosis, Candida glabrata, Candida auris	Inhibits adhesion, colonization, biofilm formation, and/or filamentation; unidentified metabolite inhibits non-albicans Candida virulence	In vitro, ex vivo, in vivo models

Note. TNFα: Tumor necrosis factor alpha & INF-γ: Interferon gamma

It is important to situate this hypothesis within the broader context of cancer-related depression, recognizing that Candida overgrowth is only one of several contributors to systemic inflammation and mood disturbance [26, 28]. As such, probiotic therapy is envisioned as a potential adjunct to–not a replacement for–existing pharmacological, psychotherapeutic, and antifungal interventions [29, 30]. Clinical implementation would require careful patient selection, ideally guided by biomarkers of mycobiome composition, gut permeability, and inflammatory status, to identify those most likely to benefit and to monitor therapeutic response [37-39].

Evaluation of the Hypothesis

The mechanistic rationale for targeting Candida overgrowth in cancer-related depression is supported by preclinical and clinical evidence. Chemotherapeutic regimens, antibiotics, and immunosuppression disrupt the normal balance of gut bacteria and fungi, leading to overgrowth of Candida, increased intestinal permeability, and translocation of fungal antigens and metabolites into systemic circulation [9, 10, 14, 15]. This triggers a cascade of immune activation and cytokine release, which is known to drive neuroinflammation and disrupt serotonergic and dopaminergic neurotransmission, contributing to depressive symptoms [11, 12, 16, 18-21]. Comparative studies have shown that Candida overgrowth is associated with more severe gut barrier dysfunction, higher systemic inflammation, and greater neuropsychiatric disturbance than other forms of dysbiosis in immunocompromised hosts [13-15, 27]. Furthermore, the production of acetaldehyde and other toxic metabolites by Candida is particularly neurotoxic and not paralleled by most bacterial species [22-25].

Probiotics have demonstrated the capacity to restore microbial equilibrium, reinforce gut barrier integrity, and reduce systemic inflammation in various disease models [40, 41]. Specifically, Lactobacillus rhamnosus L34 reduced Candida-induced colitis and systemic inflammation in murine models [13], and Saccharomyces boulardii has shown efficacy in reducing Candida colonization and gut permeability in both animal and human studies [33, 34]. Several clinical trials and meta-analyses have reported improvements in depressive symptoms with multi-strain probiotics, including Lactobacillus and Bifidobacterium species, in non-cancer populations [8, 34], although direct evidence in cancer patients with candidiasis remains limited. Importantly, preclinical evidence supports the antagonism of Candida by select probiotic strains, mediated by competitive exclusion, production of antifungal peptides, and modulation of host immunity [13, 33, 34]. This provides a strong theoretical basis for clinical exploration in oncology.

Current antifungal treatments (e.g., fluconazole and echinocandins) are effective for invasive candidiasis but are associated with risks of resistance, drug interactions, and toxicity, especially in patients already burdened by polypharmacy [10]. Moreover, these agents do not restore microbial balance or address underlying dysbiosis, potentially allowing for recurrence or persistence of low-grade inflammation. Probiotics may offer a complementary strategy, targeting both the pathogen and the milieu that supports its overgrowth, while also addressing mood-related pathways [33, 34, 40].

Hypothesis Testing

A robust evaluation of this hypothesis requires a sequential integration of preclinical and clinical studies. Initial research should use animal models that mimic immune-compromised, tumor-bearing conditions with induced Candida overgrowth and depressive-like behaviors, in order to assess the effects of candidate probiotic strains such as Lactobacillus rhamnosus L34, Saccharomyces boulardii, and Lactobacillus plantarum on behavioral, immunological, and microbiome outcomes [13, 42]. Advanced techniques–including microbiome sequencing, cytokine profiling, and neurochemical analyses–should be employed to clarify underlying mechanisms and identify predictive biomarkers of response [38, 42]. Subsequent translational studies should involve well-designed pilot randomized controlled trials (RCTs) in cancer patients with confirmed Candida overgrowth (determined by stool culture, PCR, or fungal marker assays) and clinically significant depressive symptoms. These trials should utilize validated depression rating scales (such as the Hamilton depression rating scale and patient health questionnaire-9), quality-of-life measures, gut permeability markers (e.g., zonulin), pro-inflammatory cytokines, and microbiota/mycobiome sequencing as outcome variables [37-39]. If initial trials demonstrate safety and efficacy, larger multicenter RCTs should be conducted to confirm external validity and to refine probiotic dosing and strain selection [43, 44]. Throughout all stages, stratification by cancer type, disease stage, treatment regimen, and baseline microbiome profiles will be crucial for managing heterogeneity [45]. Longitudinal study designs are recommended to assess the durability of observed effects and potential impacts on cancer progression [46]. Future clinical trials should also incorporate rigorous methodological frameworks, including sample size calculations, clearly defined primary and secondary endpoints, appropriate control groups, sufficient follow-up periods, and adequate blinding and placebo control strategies. Recruitment should focus on assembling sufficiently homogeneous patient cohorts to enable meaningful subgroup analyses.

Safety Considerations

Despite preliminary evidence of safety for certain strains, the real-world risk of probiotic-associated bacteremia or fungemia in immunocompromised hosts warrants cautious, protocolized risk stratification and monitoring–especially in patients with severe neutropenia or central venous catheters [44]. To mitigate risks, only well-characterized, clinically validated strains with established safety profiles should be used, and patients monitored for adverse events [43, 44]. Probiotics must be manufactured under stringent good manufacturing practice conditions to prevent contamination, and administration should be avoided in patients with severe immunosuppression or ongoing mucositis until safety is unequivocally established. Close collaboration with infectious disease specialists and monitoring of infection biomarkers are recommended during clinical trials [44]. However, long-term safety data and regulatory guidance for probiotic use in oncology are currently insufficient and should be a focus of future research.

Clinical Implementation

Clinical implementation of probiotic therapy in oncology should involve detailed protocols for patient risk stratification, continuous monitoring for adverse events, and rapid management of infectious complications. When integrating probiotics into cancer care, clinicians must carefully consider treatment burden, existing comorbidities, and patient preferences. Probiotics may be used as an adjunct to standard antidepressant or antifungal therapy, with patient selection guided by baseline mycobiome profiles and inflammatory biomarkers to optimize benefits and minimize risks [37, 39]. It is essential to educate both clinicians and patients about the rationale and evidence supporting psychobiotic use in this setting, alongside ongoing surveillance for potential adverse effects. Furthermore, health economic analyses should evaluate the cost-effectiveness of probiotic interventions, particularly if they reduce hospitalizations or improve quality of life [47]. Successful real-world implementation will require multidisciplinary collaboration among oncologists, psychiatrists, microbiologists, and pharmacists.

Limitations and Future Directions

The proposed hypothesis is constrained by several limitations. While Candida overgrowth may contribute to inflammation and depressive symptoms in some cancer patients, depression in oncology is a complex, multifactorial disorder with numerous established etiologies, such as direct neurotoxic effects of chemotherapy, tumor biology, and psychosocial stressors. Thus, the potential impact of probiotics targeting Candida should be considered as one component within a broad, integrative management framework, not as a singular or dominant pathway [26, 28]. Heterogeneity in cancer type, treatment, host genetics, and microbiome composition complicates patient selection and generalizability [42]. Probiotic efficacy is highly strain- and dose-dependent, with substantial heterogeneity observed across different formulations. Optimal strain selection, combinations, and dosing regimens for immunocompromised cancer patients have yet to be established and represent a critical research gap [43]. Reliable diagnosis of subclinical Candida overgrowth remains challenging due to limited sensitivity and specificity of current diagnostic tools–including stool cultures, PCR, and serological fungal markers. Moreover, there is a lack of standardized, validated biomarkers to identify cancer patients most likely to benefit from targeted probiotic interventions [39]. Safety concerns in immunocompromised patients necessitate cautious, stepwise clinical evaluation [44]. The durability of mental health improvements and the potential effects on cancer outcomes require longitudinal study [46]. Future research should prioritize the identification and validation of biomarkers (e.g., mycobiome signatures, gut permeability markers, and cytokines) to guide therapy and should explore synergistic combinations with antifungals or dietary interventions [37, 39]. In addition, potential pharmacological interactions between probiotics and conventional antifungal or antidepressant medications, as well as possible effects on the efficacy and safety of cancer

therapies such as chemotherapy or immunotherapy, remain largely unexplored and should be routinely evaluated in future clinical studies. Finally, confounding factors such as dietary patterns, recent or concurrent antibiotic use, cancer type and stage, and history of microbiome-altering interventions may influence both the presence of Candida overgrowth and the clinical response to probiotics. Future studies should incorporate stratification or adjustment for these variables to enhance interpretability and generalizability.

CONCLUSIONS

This article proposes an integrative approach to addressing depression in cancer patients by focusing on Candida-driven dysbiosis and the potential of targeted probiotic therapy. However, because current evidence is still preliminary, it is important not to overstate the likely clinical benefits of such microbiome-targeted interventions. Ethical issues, such as ensuring informed consent and managing patient expectations, should be carefully considered when introducing these therapies to vulnerable cancer populations. Further translational research is necessary to determine their safety, effectiveness, and best practices. If proven successful, this strategy could significantly improve holistic care in oncology by enhancing the management of psychiatric comorbidities and overall patient outcomes.

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Data sharing statement: Data supporting the findings and conclusions are available upon request from the author.

REFERENCES

1. Getie A, Ayalneh M, Bimerew M. Global prevalence and determinant factors of pain, depression, and anxiety among cancer patients: An umbrella review of systematic reviews and meta-analyses. BMC Psychiatry. 2025;25:156. https://doi.org/10.1186/s12888-025-06599-5 PMid: 39972435 PMCid:PMC11841195
2. Hou K, Wu Z-X, Chen X-Y, et al. Microbiota in health and diseases. Signal Transduct Target Ther. 2022;7(1):135. https://doi.org/10.1038/s41392-022-00974-4 PMid: 35461318 PMCid:PMC9034083
3. Gupt A, Naudiyal S, Rani A, Kumar S. Mental health and the microbiome: A review of psychological impacts of gut microflora. Curr Pharmacol Rep. 2024;10(4):223-36. https://doi.org/10.1007/s40495-024-00357-z
4. Paray BA, Albeshr MF, Jan AT, Rather IA. Leaky gut and autoimmunity: An intricate balance in individuals health and the diseased state. Int J Mol Sci. 2020;21(24):9770. https://doi.org/10.3390/ijms21249770 PMid:33371435 PMCid:PMC7767453
5. Jiang H-Y, Pan L-Y, Zhang X, Zhang Z, Zhou Y-Y, Ruan B. Altered gut bacterial-fungal interkingdom networks in patients with current depressive episode. Brain Behav. 2020;10(8):e01677. https://doi.org/10.1002/brb3.1677 PMid:32533650 PMCid:PMC7428472
6. Mirzaei R, Bouzari B, Hosseini-Fard SR, et al. Role of microbiota-derived short-chain fatty acids in nervous system disorders. Biomed Pharmacother. 2021: 139:111661. https://doi.org/10.1016/j.biopha.2021.111661 PMid:34243604
7. Bonaz B, Sinniger V, Pellissier S. The vagus nerve in the neuro-immune axis: Implications in the pathology of the gastrointestinal tract. Front Immunol. 2017:8:1452. https://doi.org/10.3389/fimmu.2017.01452 PMid:29163522 PMCid:PMC5673632
8. Ferrari S, Mulè S, Parini F, et al. The influence of the gut-brain axis on anxiety and depression: A review of the literature on the use of probiotics. J Tradit Complement Med. 2024;14(3):237-55. https://doi.org/10.1016/j.jtcme.2024.03.011 PMid:38707924 PMCid:PMC11069002
9. Teoh F, Pavelka N. How chemotherapy increases the risk of systemic candidiasis in cancer patients: Current paradigm and future directions. Pathogens. 2016;5(1):6. https://doj.org/10.3390/pathogens5010006 PMid: 26784236 PMCid:PMC4810127
10. Galloway-Peña JR, Kontoyiannis DP. The gut mycobiome: The overlooked constituent of clinical outcomes and treatment complications in patients with cancer and other immunosuppressive conditions. PLoS Pathog. 2020;16(4): e1008353. https://doi.org/10.1371/journal.ppat.1008353 PMid:32240277 PMCid:PMC7117661
11. Kumamoto CA. Inflammation and gastrointestinal Candida colonization. Curr Opin Microbiol. 2011;14(4):386-91. https://doi.org/10.1016/j.mib.2011.07.015 PMid:21802979 PMCid:PMC3163673
12. Hassamal S. Chronic stress, neuroinflammation, and depression: An overview of pathophysiological mechanisms and emerging anti-inflammatories. Front Psychiatry. 2023:14:1130989. https://doi.org/10.3389/fpsyt.2023.1130989 PMid:37252156 PMCid:PMC10213648
13. Panpetch W, Hiengrach P, Nilgate S, et al. Additional Candida albicans administration enhances the severity of dextran sulfate solution induced colitis mouse model through leaky gut-enhanced systemic inflammation and gut-dysbiosis but attenuated by Lactobacillus rhamnosus L34. Gut Microbes. 2020;11(3):465-80. https://doi.org/10.1080/19490976.2019.1662712 PMid:31530137 PMCid: PMC7527076
14. Zaongo SD, Ouyang J, Isnard S, et al. *Candida albicans* can foster gut dysbiosis and systemic inflammation during HIV infection. Gut Microbes. 2023;15(1):2167171. https://doi.org/10.1080/19490976.2023.2167171 PMid: 36722096 PMCid:PMC9897780
15. Gaspar BS, Roşu OA, Enache RM, Manciulea M, Pavelescu LA, Creţoiu SM. Gut mycobiome: Latest findings and current knowledge regarding its significance in human health and disease. J Fungi. 2025;11(5):333. https://doi.org/10.3390/jof11050333 PMid:40422666 PMCid:PMC12112676
16. Rhie SJ, Jung EY, Shim I. The role of neuroinflammation on pathogenesis of affective disorders. J Exerc Rehabil. 2020;16(1):2-9. https://doi.org/10.12965/jer.2040016.008 PMid:32161729 PMCid:PMC7056473

17. Alejandra MR, Noé MS. Neuro-immune-endocrine interactions during infections. In: Guerrero Manriquez GG, ed. Anti-infective research and development: Updates on infection mechanisms and treatments. Singapore: Bentham Science Publishers; 2020. p. 125-49. https://doi.org/10.2174/9789811469589120020008
18. Di Vincenzo F, Del Gaudio A, Petito V, Lopetuso LR, Scaldaferri F. Gut microbiota, intestinal permeability, and systemic inflammation: A narrative review. Intern Emerg Med. 2024;19(2):275-93. https://doi.org/10.1007/s11739-023-03374-w PMid:37505311 PMCid:PMC10954893
19. El-Sehrawy AA, Ayoub II, Uthirapathy S, et al. The microbiota-gut-brain axis in myalgic encephalomyelitis/chronic fatigue syndrome: A narrative review of an emerging field. Eur J Transl Myol. 2025;35(1):13690. https://doi.org/10.4081/ejtm.2025.13690 PMid:39937103 PMCid:PMC12038572
20. Hsu CY, Ahmad I, Maya RW, et al. The potential therapeutic approaches targeting gut health in myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS): A narrative review. J Transl Med. 2025;23(1):530. https://doi.org/10.1186/s12967-025-06527-x PMid: 40350437 PMCid:PMC12066075
21. Sălcudean A, Bodo CR, Popovici RA, et al. Neuroinflammation–A crucial factor in the pathophysiology of depression–A comprehensive review. Biomolecules. 2025;15(4):502. https://doi.org/10.3390/biom15040502 PMid:40305200 PMCid:PMC12024626
22. Adil NA, Omo-Erigbe C, Yadav H, Jain S. The oral-gut microbiome-brain axis in cognition. Microorganisms. 2025;13(4):814. https://doi.org/10.3390/microorganisms13040814 PMid:40284650 PMCid:PMC12029813
23. Stamation R. Endogenous ethanol production in the human alimentary tract: A literature review. J Gastroenterol Hepatol. 2025;40(4):783-90. https://doi.org/10.1111/jgh.16869 PMid:39853762 PMCid:PMC11968154
24. Lopes JP, Lionakis MS. Pathogenesis and virulence of Candida albicans. Virulence. 2022;13(1):89-121. https://doi.org/1080/21505594.2021.2019950 PMid: 34964702 PMCid:PMC9728475
25. Uittamo J, Siikala E, Kaihovaara P, Salaspuro M, Rautemaa R. Chronic candidosis and oral cancer in APECED-patients: Production of carcinogenic acetaldehyde from glucose and ethanol by Candida albicans. Int J Cancer. 2009;124(3):754-6. https://doi.org/10.1002/ijc.23976 PMid:18975379
26. Fraile-Martinez O, Alvarez-Mon MA, Garcia-Montero C, et al. Understanding the basis of major depressive disorder in oncological patients: Biological links, clinical management, challenges, and lifestyle medicine. Front Oncol. 2022;12:956923. https://doi.org/10.3389/fonc.2022.956923 PMid:36185233 PMCid:PMC9524231
27. Hadrich I, Turki M, Chaari I, et al. Gut mycobiome and neuropsychiatric disorders: Insights and therapeutic potential. Front Cell Neurosci. 2025;18:1495224. https://doi.org/10.3389/fncel.2024.1495224 PMid: 39845646 PMCid:PMC11750820
28. Priego-Parra BA, Remes-Troche JM. Bidirectional relationship between gastrointestinal cancer and depression: The key is in the microbiota-gut-brain axis. World J Gastroenterol. 2024;30(48):5104-10. https://doi.org/10.3748/wjg.v30.i48.5104 PMid:39735265 PMCid: PMC11612697
29. Verma A, Inslicht SS, Bhargava A. Gut-brain axis: Role of microbiome, metabolomics, hormones, and stress in mental health disorders. Cells. 2024;13(17):1436. https://doi.org/10.3390/cells13171436 PMid:39273008 PMCid:PMC11394554
30. AnaMaria C, Vodnar DC. Exploring the gut-brain Axis: Potential therapeutic impact of psychobiotics on mental health. Prog Neuropsychopharmacol Biol Psychiatry. 2024:134:111073. https://doi.org/10.1016/j.pnpbp.2024.111073 PMid:38914414
31. Juarez VM, Montalbine AN, Singh A. Microbiome as an immune regulator in health, disease, and therapeutics. Adv Drug Deliv Rev. 2022;188:114400. https://doi.org/10.1016/j.addr.2022.114400 PMid:35718251 PMCid:PMC10751508
32. Zheng D, Liwinski T, Elinav E. Interaction between microbiota and immunity in health and disease. Cell Res. 2020;30(6):492-506. https://doi.org/10.1038/s41422-020-0332-7 PMid:32433595 PMCid:PMC7264227
33. Chakravarty K, Gaur S, Kumar R, Jha NK, Gupta PK. Exploring the multifaceted therapeutic potential of probiotics: A review of current insights and applications. Probiotics Antimicrob Proteins. 2025;17(1):341-63. https://doi.org/10.1007/s12602-024-10328-x PMid: 39069588
34. Yuan X, Chai J, Xu W, Zhao Y. Exploring the potential of probiotics and prebiotics in major depression: From molecular function to clinical therapy. Probiotics Antimicrob Proteins. 2024;16(6):2181-217. https://doi.org/10.1007/s12602-024-10326-z PMid:39078446
35. Vazquez-Munoz R, Dongari-Bagtzoglou A. Anticandidal activities by Lactobacillus species: An update on mechanisms of action. Front Oral Health. 2021;2:689382. https://doi.org/10.3389/froh.2021.689382 PMid:35048033 PMCid:PMC8757823
36. Kunyeit L, KA AA, Rao RP. Application of probiotic yeasts on Candida species associated infection. J Fungi. 2020;6(4):189. https://doi.org/10.3390/jof6040189 PMid: 32992993 PMCid:PMC7711718
37. Schmidt ME, Maurer T, Behrens S, Seibold P, Obi N, Chang-Claude J, et al. Cancer-related fatigue: Towards a more targeted approach based on classification by biomarkers and psychological factors. Int J Cancer. 2024;154(6):1011-8. https://doi.org/10.1002/ijc.34791 PMid:37950650
38. Kim HJ, Chae KM, Jung SO, Chung SW, Raykov T. Psychological and biological stress pathways as common mechanisms underlying a psycho-neurological symptom cluster in cancer patients: Perceived stress, cortisol, and ACTH. Eur J Oncol Nurs. 2025;74:102728. https://doi.org/10.1016/j.ejon.2024.102728 PMid:39561471
39. Pitarch A, Nombela C, Gil C. Diagnosis of invasive candidiasis: From gold standard methods to promising leading-edge technologies. Curr Top Med Chem. 2018;18(16):1375-92. https://doi.org/10.2174/1568026618666181025093146 PMid:30360714
40. Chakravarty K, Gaur S, Kumar R, Jha NK, Gupta PK. Exploring the multifaceted therapeutic potential of probiotics: A review of current insights and applications. Probiotics Antimicrob Proteins. 2025;17(1):341-63. https://doi.org/10.1007/s12602-024-10328-x PMid: 39069588

41. Kiran NS, Chatterjee A, Yashaswini C, et al. The gastrointestinal mycobiome in inflammation and cancer: Unraveling fungal dysbiosis, pathogenesis, and therapeutic potential. Med Oncol. 2025;42(6):195. https://doi.org/10.1007/s12032-025-02761-x PMid:40323477
42. Kuntz TM. Towards molecular microbial medicine. Chicago, IL: The University of Chicago; 2019.
43. Haranahalli Nataraj B, Behare PV, Yadav H, Srivastava AK. Emerging pre-clinical safety assessments for potential probiotic strains: A review. Crit Rev Food Sci Nutr. 2024;64(23):8155-83. https://doi.org/10.1080/10408398.2023.2197066 PMid:37039078
44. Miarons M, Roca M, Salvà F. The role of pro-, pre-and symbiotics in cancer: A systematic review. J Clin Pharm Ther. 2021;46(1):50-65. https://doi.org/10.1111/jcpt.13292 PMid:33095928
45. Group Young Researchers in Inflammatory Carcinogenesis, Wandmacher AM, Mehdorn AS, Sebens S. The heterogeneity of the tumor microenvironment as essential determinant of development, progression and therapy response of pancreatic cancer. Cancers. 2021;13(19):4932. https://doi.org/10.3390/cancers13194932 PMid:34638420 PMCid:PMC8508450
46. de Sousa RD, Zagalo DM, Costa T, de Almeida JM, Canhão H, Rodrigues A. Exploring depression in adults over a decade: A review of longitudinal studies. BMC Psychiatry. 2025;25(1):378. https://doi.org/10.1186/s12888-025-06828-x PMid:40234864 PMCid:PMC11998219
47. Więckiewicz G, Weber S, Florczyk I, Gorczyca P. Socioeconomic burden of psychiatric cancer patients: A narrative review. Cancers. 2024;16(6):1108. https://doi.org/10.3390/cancers16061108 PMid:38539443 PMCid:PMC10969503