

Probiotics for the mind: How gut bacteria may affect our mental health

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Abstract

The human gut with its complex microbial community, the so-called gut microbiota, is also of relevance for the research field of neuroscience. Recent studies have shown that the gut and the microorganisms living in the gut, communicate bidirectionally with the central nervous system and may influence brain functions and behavior. Disorders of this bidirectional communication system, also known as 'gut-brain axis', might be involved in the development of neurological and mental disorders. Preclinical and clinical studies indicate that probiotics modulate the gut microbiota and therewith may have a preventive effect on progression of neurological and mental diseases. By elucidating the underlying mechanisms and performing further clinical trials, probiotics may possibly be considered as a new approach for the treatment of mental illnesses such as depression and anxiety disorders.

Keywords: microbiota, gut-brain axis, probiotics, depression, anxiety, mind, "psychobiotics"

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Introduction

With up to 10^{13} bacteria and more than a hundred bacterial species, the gastrointestinal tract contains the largest proportion of the physiological human flora. These bacteria are mainly commensals and usually live in symbiosis with their host. The totality of all microorganisms colonizing the human organism, including their genetic material, is called microbiome. The development of the human microbiome is a complex process that is crucial for the physiology of the organism and begins with birth. The fetal, germ-free intestine is colonized during birth with microorganisms from the birth canal or from the skin of the mother. The microbiome changes continuously during life span. Influencing factors such as genetics, age, gender, geography, stress level and health conditions can affect the diversity and composition of the gut microorganisms [1].

Our understanding of the complexity and diversity of the microbiome is mainly due to the advancement in sequencing technology, which allows detailed analysis of all bacteria and viruses that colonize the human organism [2]. Today, it is known that the intestinal microorganisms play a significant role in the maintenance of a physiological homeostasis as well as in the pathogenesis of various diseases. Furthermore, intestinal microorganisms make a major contribution to the human metabolism by fermenting indigestible dietary fibers into short-chain fatty acids (SCFA) and thus supplying their host with energy. In addition, intestinal microorganisms have important immunomodulating properties and support the intestinal barrier function [3]. It is assumed that even a miscolonization of the intestine in infancy can lead to an increased risk of disease in later stages of life [4]. There even is strong evidence that the gut microbiome has an impact on cognitive and emotional processes via the so-called 'gut-

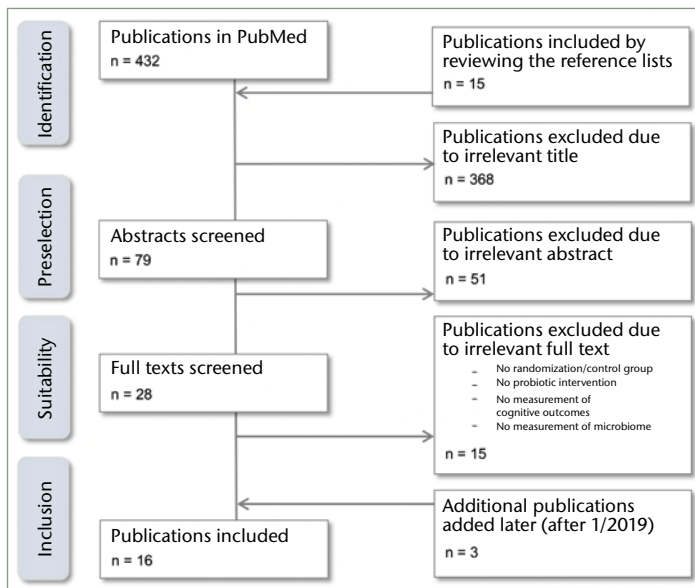


Figure 1: PRISMA flow chart of study selection
 PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses

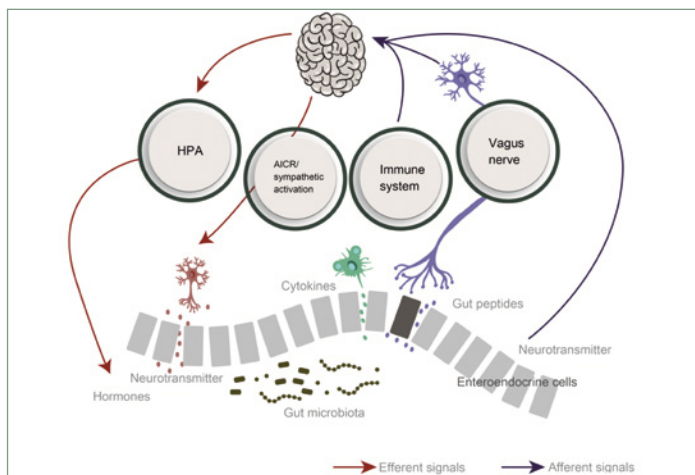


Figure 2: Microbiota gut-brain axis
 Direct and indirect signaling pathways support bidirectional communication between the gut microbiota and the central nervous system; endocrine, neural and immunological signals are involved.
 Afferent signals (blue): Immune system-dependent secreted cytokines have an endocrine or paracrine effect. Sensory neural terminals, e.g., on the vagus nerve, can be activated by intestinal peptides secreted by enteroendocrine cells. Neurotransmitter and their precursors produced as metabolites of the microbiota can reach the intestinal epithelium and mediate endocrine and paracrine effects.
 Hypothalamic activation initiates the efferent (red): Corticosteroid hormones released as a result of hypothalamic-pituitary-adrenal (HPA) axis activation have a modulatory effect on the gut microbiota. The "anti-inflammatory cholinergic reflex" (AICR) and/or sympathetic activation release neurotransmitters that can also modulate the gut microbiota.

brain axis' and can play an important role in brain development. Animal studies have shown that a change in the gut microbiome affects signaling along the gut-brain axis and can affect anxiety- and stress-related behavior [5]. Even mental illnesses in humans are strongly associated with dysfunctions of the gut-brain axis communication system. With regard to this dysbiosis and the impact of the intestinal microbiota, interest in research on probiotics in the prevention and treatment of mental disor-

ders emerged. Probiotics are living microorganisms within food products or additives in food that bring health benefits to their host. According to the current state of research, probiotics can influence not only the intestine itself, but also the psyche and the mind via the communication system of the gut and the brain. For example, preclinical studies have shown that certain types of bacteria have antidepressive or anxiolytic effects. This has led to the postulation of the term 'psychobiotics': a class of probiotics that affect the gut-brain axis by producing neuroactive substances, reducing the activity of the hypothalamic-pituitary-adrenal axis (HPA axis) and regulating cytokine production [7].

As stress-related diseases such as depression and anxiety disorders are among the leading causes of incapacity to work worldwide and as major contributors to the global burden of disease [8], raising awareness of these diseases is just as important as the understanding of their pathogenesis.

Therefore, in this review the underlying mechanisms of probiotics are considered and their possible therapeutic and preventive benefits are discussed.

Methods

At the beginning of 2019, a systematic literature research was conducted on the database NCBI PubMed. The search strategy included various search terms on the topics depression, anxiety, gut-brain axis und probiotic. No restrictions have been made on the publication date. Randomized, blinded and placebo-controlled preclinical and clinical intervention studies as well as meta-analyses and their references were taken into account. Regarding the study population, no restrictions have been made on the number, age, sex or ethnicity of the subjects. We included healthy and for mental disorders predisposed persons as well as persons who have already diagnosed with mental disorders. In addition, studies were considered that measured the effect of probiotics on depression-related symptoms (psychological stress, emotional behavioral disorders, mood fluctuation, anxiety) using comparable investigation methods and scientific assessment criteria. We included studies that collected blood and tissue samples or used behavioral tests or self-assessment scales. Subsequently, relevant arti-



cles published after the systematic search was completed were added to the analysis (♦ Figure 1).

The gut-brain axis

In 1833, the Canadian military physician William laid the first important milestone in the research of the gut-brain axis, when he observed that the change in stomach secretion caused by a gastric fistula affected a patient's mood [9]. Today it is known that the microbiota-gut-brain axis is a complex system that is not only responsible for the maintenance and coordination of gastrointestinal functions, but also enables bidirectional feedback between the gut and the brain. The direction of signaling is essentially determined by afferent and efferent neural pathways and immunological, neuroendocrine and metabolic factors [10]. Several factors that influence the composition and stability of the gut microbiota can also affect signaling along the gut-brain axis. Animal models show that induced modifications of the gut microbiome affect stress reactivity, anxiety and the activation of the HPA axis [5]. A comprehensive understanding of the exact mechanisms of the gut-brain axis is therefore of extraordinary importance in clarifying the development of stress-related diseases, including anxiety disorders and depression.

The hypothalamic-pituitary-adrenal axis

The HPA axis is an essential component of the bidirectional communication between the brain and the gut and is considered one of the most important endocrine systems for maintaining homeostasis under stress [11]. Of particular relevance in this context are stress hormones, which are important components of the feedback loop between the hormone glands hypothalamus, pituitary and adrenal cortex. Stress induces the activation of those hormone glands via limbic cortical pathways and then inhibits within a negative feedback mechanism the hippocampus and hypothalamus. In particular, the activation of the HPA axis through the exposure to physical and psychological stressors is important for the stress response, since this causes a release of the corticotropin-releasing hormone (CRF), which subsequently stimulates the release of glucocorticoids from the adrenal cortex. Therefore, HPA axis activity can be assessed based on the concentration of cortisol in humans and corticosterone in rodents [12]. Changes in the HPA axis activity are associated with the development of mood disorders; in depressed patients the presence of dysregulation of the HPA axis is undisputed [13].

Immunomodulation und endocrine parameters

The modulation of the immune system is a further important pathway of the gut-brain axis. This modulation occurs through the activation of toll-like receptors of the innate immune system, which can detect specific structural components of various bacteria and cause a release of pro-inflammatory and anti-inflammatory cytokines. Through numerous pathways, these cytokines can reach the brain

and trigger pro-inflammatory reactions or reduce serotonin production.

The gut microbiota influences the immune response and can strengthen the intestinal barrier against pathogenic bacteria. It is assumed that the gut microbiota has an impact on the immune system of the host, for example on the response of regulatory T cells (T_{reg}) [14], via microbial metabolite-dependent mechanisms [15]. These metabolites are, for example SCFA. A recent study in MS patients showed that the exogenous application of propionic acid increased the number of T_{reg} , which regulate the self-tolerance of the immune system, sustainably and significantly. At the same time, the number of TH1 and TH17 cells associated with chronic inflammation and autoimmune diseases decreased significantly. The subsequent analysis of the microbiome of patients treated with SCFA showed an increased expression of T_{reg} inducing genes [16]. Even in an animal model it was observed that SCFA, as a product of microbial fermentation, modulated the size and functionality of the T_{reg} pool of the gut [14]. Numerous studies describe that inflammation of the gastrointestinal tract is associated with increased anxious or depressive behavior. It is assumed that the microbiome plays a central role in this context [13, 17]. In this regard, it has been shown that the experimental modulation of the endotoxin lipopolysaccharides (LPS) in healthy individuals led to the appearance of anxiety- and depression-associated symptoms as well as an increase in the concentration of stress hormones and pro-inflammatory cytokines [18]. Even oral administered probiotics have immunomodulating properties, which have not yet been entirely researched. Probiotics are able to affect immune cells of the gut. Human studies as well as animal models have shown that oral probiotics modulated the cytokine profile by lowering the concentrations of pro-inflammatory cytokines and increasing the concentration of anti-inflammatory cytokines in the blood [3, 19, 20]. Neuroendocrine factors involved in the regulation of the gut-brain axis include cortisol, norepinephrine, serotonin, melatonin,



gamma-aminobutyric acid (GABA) and CRF. A variety of neurotransmitters is produced by the bacteria of the gut microbiota itself [3].

Effects of probiotics on behavior and mood in animal studies

Behavioral tests

In order to characterize the depression- and stress-associated behavior in preclinical studies, various test methods were used to determine the anxiety and exploratory behavior in healthy animals [19, 21–23] as well as in stressed animals [20]. All animals showed an altered symbiotic microbiota and an increased stress reactivity. The intervention group was treated with single- to two-strain [19–23] or multi-species probiotics [19] while the control group received a placebo drug (♦ Table 1).

In all animal studies analyzed here, positive, probiotic-induced effects on behavior in stressful situations or depression-associated behavior were shown in at least one of the behavioral tests performed [19–23]. The animals treated with probiotics were more curious, less anxious and less hopeless in the behavioral tests and showed improved adaptation to stressful situations. Immobility and swimming time were improved in the Forced Swim Test (FST), which was interpreted as reduced hopelessness or increased will to survive [19, 20, 23]. In the Elevated Plus Maze (EPM) test, animals treated with probiotics stayed longer in anxiety-inducing situations [21, 23]; in the Open Field Test, the time it required for the animals to enter an anxiety-inducing situation was shortened [21] and the time and frequency with which the animals stayed within this situation increased [23]. These changes were interpreted as anxiety-reducing. Also in the Defensive Burying Test positive effects of the probiotic treatment on the anxiety and stress behavior was described [22]. In addition, strain specific effects of the probiotic intervention were observed within the behavioral tests. For example, two different bacterial strains of *Bifidobacterium* each showed an individual therapeutic effect in acute stress and depression (*B. longum* 1714) or on anxiety and body weight (*B. breve* 1205) [21].

HPA axis activity

Within investigations on the HPA axis activity it was shown that the exposure to acute stressors led to increased plasma concentrations of corticosterone [21]. The administration of probiotics reduced [23] or did not affect this increase in concentration [20, 21]. In addition, it was observed that young rats separated from the mother postnatal had a higher expression of CRF mRNA in the amygdala. A subsequent probiotics application could only slightly reduce CRF mRNA expression [20]. However, at the hippocampal transcriptional level the activity of the CRF1 and CRF2 receptors was significantly reduced by probiotic treatment [19]. This indicates a reduction in the stress level of the study animals.

Neurotransmitter und cytokine profile

Positive probiotic-induced effects were also observed on neurotransmitter secretion, which is considered as a key element of the gut-

brain communication. In this respect, changes in mRNA expression of GABA receptors in various brain regions have been described [23]. In addition, the concentration of norepinephrine in the pons, which had been reduced by stress, could be normalized by probiotic treatment [20]. Even a favorable shift in the cytokine profile was achieved [19, 20].

Effects of probiotics on behavior and mood in human intervention studies

Depression-, anxiety- and stress related symptoms

Human studies investigated the influence of probiotics on the mind and psyche in healthy participants [22, 29, 30, 32], for mental disorders predisposed persons [25, 27, 28, 31] and patients with mild to severe depressive disorders [24, 26]. In order to characterize the symptoms associated with depression, anxiety and stress in the subjects, self-assessment scales were collected (♦ Table 2). The intervention period was between 14 days and 8 weeks.

The summarized results of the studies indicate that probiotics can have a stimulating effect on mood in healthy or for mental disorders predisposed persons as well as in patients with mild to severe depressive disorders.

In subjects with diagnosed severe depression (MDD), a treatment with a multi-species probiotic led to a reduction in depressive symptoms in the Beck Depression Inventory Test (BDI) [26]. These results could not be confirmed in subjects with chronic fatigue syndrome, but here the Beck Anxiety Inventory Test (BAI) showed a reduction in anxiety symptoms within the treated group [31]. In healthy subjects, neither in BDI nor BAI an improvement due to probiotic intervention has been described [25, 29]. However, in the Leiden Index of Depression Sensitivity (LEIDS-r), cognitive reactivity to sad mood, aggressive and brooding thoughts was reduced [29]. In addition, in healthy subjects a probiotic supplementation led to stronger relaxation of the psychological load [30]. In healthy volunteers who were assessed as rather depressed at baseline, the consumption of a probiotic milk drink resulted in an improvement in mood in the Profile of Mood States Test (POMS) [32]. In subjects predisposed by their work in the petrochemical industry, the General Health Questionnaire (GHI) and Depression, Anxiety and Stress Scale (DASS) showed an improvement in mental state through probiotics



Author, year	Subjects, duration	Species, dose	Test methods	Results
Abildgaard, 2017 [19]	40 Sprague-Dawley rats (m) 5 wks	<i>B. bifidum</i> W23, <i>B. lactis</i> W52, <i>L. acidophilus</i> W37, <i>L. brevis</i> W63, <i>L. casei</i> W56, <i>L. salivarius</i> W24, <i>Lactococ. lactis</i> W19 & W58 2,5 x 10 ⁹ cfu/g	BM, FST, OF, OGTT Blood samples, brain tissue samples	Antidepressive effects (FST)
Savignac, 2014 [21]	88 BALB/c mice (m) 6 wks	<i>B. longum</i> 1714 or <i>B. breve</i> 1205 or antidepressant Escitalopram, 1 x 10 ⁹ cfu/mL	SIH, DMB, EPM, OF, FST, TST Corticosterone, weight of different tissues, body weight	Anxiety behavior ↓ (SIH, DMB, EPM, OF)
Messaoudi, 2011 [22]	36 Wistar rats (m) 2 wks	<i>L. helveticus</i> R0052, <i>B. longum</i> R0175 3 x 10 ⁹ cfu/1,5 g	Conditioned DB	Stress-related behavior, anxiety behavior ↓
Bravo, 2011 [23]	36 BALB/c mice (m) 4 wks	<i>L. rhamnosus</i> (JB-1) 1 x 10 ⁹ cfu	SIH, EPM, FST, OF, FC Blood samples, brain tissue samples	Antidepressive and anxiolytic effects (EPM, FST, OF, FC)
Desbonnet, 2010 [20]	33 Sprague-Dawley rats (m) [†] 45 d	<i>B. infantis</i> 35624 or antidepressant Citalopram, 1 x 10 ¹⁰ cfu/100 mL	FST Blood samples, brain and gut tissue samples	Normalized behavior deficits

Table 1: Preclinical studies on the effects of probiotics on behavior and mood in behavioral testing.

↓ Positive behavioral changes within the intervention group in comparison to the control group
 BM = Barnes maze, cfu = Colony Forming Unit, d = days, DB = Defensive Burying Test, DMB = Defensive Marble Burying Test, EPM = Elevated Plus Maze, FC = Fear Conditioning, FST = Forced Swim Test, m = male, OF = Open Field Test, OGTT = Oral Glucose Tolerance Test, SIH = Stress-induced Hyperthermia, TST = Tail Suspension Test, wks = weeks
[†]22 of 33 rats were separated from the mother postnatally

from capsules and yoghurt [27].

Subjects who were mentally pre-stressed by an upcoming operation also benefited from the preoperative intake of probiotics, so a reduction in the level of anxiety in the Hamilton Anxiety Scale was shown [28]. On the other hand, in subjects predisposed by their work in shifts, no benefits of the probiotic intervention were observed [25].

A similar conclusion to the reviewed human studies is also found in two meta-analyses of clinical intervention studies that investigated the effect of probiotics in depression: It is described that probiotics intake in both healthy volunteers [34] and depressive patients significantly improved depression-associated symptoms [33, 34].

HPA axis activity

Two of the reviewed clinical studies investigated the effect of probiotic interventions on HPA axis activity using biological parameters.

Preoperative subjects not treated with probiotics showed stress-induced elevated serum CRF concentrations due to the upcoming surgery. In the intervention group treated with probiotics, however, the serum CRF concentration remained stable and did not increase preoperatively [28]. Even in healthy subjects a probiotic supplementation led to a decrease in the urine concentration of free cortisol, which indicates a reduction of the patients' stress level [30].

Oxidative stress

One of the reviewed clinical studies assessed inflammatory status and antioxidant potential in MDD patients. Here it was shown that a probiotic supplementation reduced the concentration of the systemic inflammatory marker C-reactive protein (CRP). At the same time, an increased concentration of plasma glutathione was observed, which implies an improved protection of cells from oxidative stress [26].

Intestinal flora

One of the reviewed clinical studies assessed the bacterial colonization of the intestine in patients with chronic fatigue syndrome. Compared to the placebo group, the probiotics group showed a moderate increase in the total number of fecal aerobic and anaerobic bacteria and an increase in the total number of fecal bifidobacteria and lactobacilli [31].



Author, year	Subjects, duration	Species, dose	Test methods	Results
Randomized controlled studies (RCTs)				
Chahwan, 2019 [24]	71 patients with mild to severe depression 8 wks	<i>B. bifidum</i> W23, <i>B. lactis</i> W51 and W52, <i>L. acidophilus</i> W37, <i>L. brevis</i> W63, <i>L. casei</i> W56, <i>L. salivarius</i> W24, <i>Lactococ. Lactis</i> W19 and W58 1 × 10 ¹⁰ cfu/T	BDI, DASS, M.I.N.I, BAI, LEIDS-r stool samples	Cognitive reactivity ↑
Smith-Ryan, 2019 [25]	41 predisposed women	<i>B. bifidum</i> W23, <i>B. lactis</i> W51, <i>B. lactis</i> W52, <i>L. acidophilus</i> W37, <i>L. brevis</i> W63, <i>L. casei</i> W56, <i>L. salivarius</i> W24, <i>Lactococ. lactis</i> W19 and W58 2,5 × 10 ⁹ cfu/T	HADS, CFQ, Exercise Fatigue Test, blood samples	↔
Akkasheh, 2016 [26]	40 MDD-patients 8 wks	<i>L. acidophilus</i> , <i>L. casei</i> , <i>B. bifidum</i> 2 × 10 ⁹ cfu/g	BDI, blood samples	BDI ↑ Insulin response, insulin resistance, hs-CRP, glutathione ↑
Mohammadi, 2016 [27]	70 predisposed patients 6 wks	Yoghurt: <i>L. acidophilus</i> LA5, <i>B. lactis</i> BB12, 1 × 10 ⁷ cfu Capsule: <i>L. casei</i> , <i>L. acidophilus</i> , <i>L. rhamnosus</i> , <i>L. bulgaricus</i> , <i>B. breve</i> , <i>B. longum</i> , <i>S. thermophiles</i> 3 × 10 ⁸ cfu/g	GHQ, DASS, blood samples	GHQ, DASS ↑
Yang, 2016 [28]	20 pre-surgical patients, 10 healthy volunteers 2 wks	<i>Clostridium butyricum</i> 420 mg/capsule	HAMA, blood samples, hearth rate	HAMA ↑ Serum-CRF
Steenbergen, 2015 [29]	40 healthy volunteers 4 wks	<i>B. bifidum</i> W23, <i>B. lactis</i> 52, <i>L. acidophilus</i> W37, <i>L. brevis</i> W63, <i>L. casei</i> W56, <i>L. salivarius</i> W24, <i>Lactococ. lactis</i> W19 & W58 2,5 × 10 ⁹ cfu	M.I.N.I, LEIDS-r, BDI, BAI	LEIDS-r ↑
Messaoudi, 2011 [30]	25 healthy volunteers 30 d	<i>L. helveticus</i> R0052, <i>B. longum</i> R0175 3 × 10 ⁹ cfu/1,5 g	HSCL-90, HADS, PSS	HSCL-90, HADS, PSS ↑
Messaoudi, 2011 [22]	55 healthy volunteers 30 d	<i>L. helveticus</i> R0052, <i>B. longum</i> R0175, 3 × 10 ⁹ cfu/1,5 g	HSCL-90, HADS, PSS, coping checklist, cortisol (urine)	HSCL-90, HADS, Coping Checklist ↑
Rao, 2009 [31]	35 CFS patients 8 wks	<i>L. casei</i> Shirota 8 × 10 ⁹ cfu/T	BDI, BAI, stool samples	BAI ↑ Changes in microbiome



Benton, 2007 [32]	124 healthy volunteers 3 wks	<i>L. casei Shirota</i> 6,5 x 10 ⁹ cfu/65 mL	POMS, NART, WMS, verbal fluency, long term memory	POMS ↑ (subgroup analysis)
Meta-analyses				
Goh, 2019 [33]	Meta-analysis 19 RCTs	Different species of Lactobacillus, Bifidobacterium and Streptococcus Various doses	DASS BDI GDS-SF HDRS HADS POMS GHQ EPDS LEIDS	Antidepressive effects in MDD patients
Huang, 2016 [34]	Meta-analysis 5 RCTs	Different species of Lactobacillus, Bifidobacterium and Streptococcus Various doses	DASS BDI HADS-D POMS	Depression scale scores ↑

Table 2: Clinical studies on the effects of probiotics on behavior and mood

↑ Positive changes within the intervention group in comparison to the control group

BDI = Beck Depression Inventory, BAI = Beck Anxiety Inventory, CFS = Chronic Fatigue Syndrome, CFQ = Chalder Fatigue Survey, CRF = Corticotropin-releasing factor, DASS = Depression Anxiety and Stress Scale, d = days, EPDS = Edinburgh Postnatal Depression Scale, GHQ = General Health Questionnaire, HADS = Hospital Anxiety and Depression Scale, HAMA = Hamilton Anxiety Scale, HDRS = Hamilton Depression Rating Scale, HOMA = Homeostasis Model Assessment, HSCL-90 = Hospital Anxiety and Depression Scale, GDS-SF = Geriatric Depression Scale Short Form, M.I.N.I = Mini International Neuropsychiatric Interview, MDD = Major Depressive Disorders, LEIDS-r = Leiden Index of Depression Sensitivity, PSS = Perceived Stress Scale, POMS = Profile of Mood States, wks = Weeks

Discussion

Results from animal models confirmed that changes in the bacterial colonization of the gut are associated with behavioral impairments. Germ-free mice, which have no symbiotic microbiota and an undeveloped immune system, were characterized by increased stress reactivity [13]. After reconstitution of the microbiota with feces of healthy mice or after administration of probiotics, stress reactions and behavioral abnormalities normalized [35]. Furthermore, it could be shown in rodents that changes in the HPA axis influenced the composition of the microbiota [36].

The probiotic-induced anxiolytic effects described in preclinical studies are comparable to the properties of novel chemical substances with anxiolytic effects [19–21, 23, 30]. These observations suggest that probiotics may have the potential to act as anxiolytics besides antidepressants [21, 23]. The use of multi-species probiotics can result in an additive effect and thus an enhanced antidepressant effect [19, 37].

With regard to the humoral stress response it has to be considered, that a reduction of stress-induced corticosterone and cortisol peaks shown in preclinical and clinical studies was mainly mediated by lactobacilli [22, 23, 30]. This implies that the effects of symbiotic gut bacteria are also stem-dependent on the neurological behavioral level. Results from further studies confirm the effect of lactobacilli on the central nervous system (CNS) [40, 41]. The results of the human studies indicate that probiotics can have

a stimulating effect on the mood of healthy persons as well as depressed or for depressions predisposed individuals. It is assumed that the efficiency of probiotics in the reduction of the stress level and in mood improvements depends on the initial stress level and general mood [30, 32]. This highlights the potential of probiotics to contribute to mental well-being in low-stressed individuals and as prevention strategy for stress-related diseases.

At the same time, it was described that probiotics mediate anti-inflammatory effects [26]. Similar properties have been shown in patients with irritable bowel syndrome, rheumatoid arthritis or during pregnancy [42–44], that were preceded by improved insulin function. This confirms the assumption that probiotics contribute to homeostasis of the gastrointestinal tract, regulate inflammation mediated reactions of the intestinal immune cells and can have a positive effect on anxiety and depression through reduced inflammatory processes.



Conclusion

Both animal studies and human clinical studies have shown that probiotics can have positive effects on behavior, mood and symptoms related to depression, anxiety and stress level. There is increasing evidence that a modulation of the gut-brain axis by probiotics could be a potential new approach for the treatment of mental disorders. However, the use of probiotics is currently not part of relevant guidelines for the treatment of mental disorders – for example the S3 guideline for unipolar depression disorders from 2015. Therefore, it is essential to examine the efficiency of probiotics and specific bacterial strains in relation to depressive and anxiety-associated symptoms in further studies in order to derive a specific therapeutic and prevention approach.

Conflict of Interest

The authors declare no conflict of interest.

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