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(Review Article)

Behaviors observed in different live species depending on nutrition

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Abstract

In order for living species to have a healthy and balanced diet, their needs for adequate amounts of protein, oil, carbohydrates, vitamins and minerals must be met. When the amount of nutrients required by the living species is not taken as much as necessary, various health problems such as psychological, as well as metabolic, physiological and chemical disorders occur. One of the fundamental indicators of psychological problems is the diet of the living thing. Excess or less of the amount of nutrients required by the living species can cause various behavioral disorders. When these behavioral disorders are examined; chronic anxiety, nervous tension and insomnia, mood and depressive symptoms, counterconditioning and depersonalization, behavioral disorders, cognitive performance and anxiety, social interaction capacity, locomotor activity, repetitive behaviors, motor coordination and seizure sensitivity, autism spectrum disorder, alzheimer's, antiepileptic it is stated in studies that it has a characteristic feature and effects on manic type bipolar disorder and migraine headache. Moreover; it is stated that the secretion of the stress hormone cortisol, social and communication disorders and restricted/repetitive behaviors, heterogeneous neurodevelopmental disorders, satiety, performance restriction, chewing behavior, stereotypical behaviors affect animal welfare, yield and performance closely. In this study, it is aimed to give information about the abnormal behaviors observed in different species depending on nutrition.

Keywords: Nutrition; Behavior; Abnormal behavior; Different species; Animals

1. Introduction

There are various responses created by living things as a result of the effects of certain stimuli. The most obvious of these various responses is behavior. Depending on the stimulus and the situation she is in, abnormal behavior is exhibited as a result of different psychological reactions [1]. These different behaviors exhibited are both genetic and; it is under the influence of environmental factors [2]. While genetic factors provide species-specific responses; environmental factors vary depending on the physiological, chemical and psychological structure of the living thing [3;4]. Among the reasons for these changes are the factors that affect the living conditions such as the environment temperature, shelter places and nutrition. For a healthy and balanced diet of living things, adequate amounts of protein, fat, carbohydrates, vitamins and minerals must be met. In addition, macro and micro elements are important in essential amino acids [1]. The amount of this nutrient required varies depending on each living species. But there is an amount that should be consumed optimally daily. It can cause various diseases such as obesity, cardiovascular diseases, diabetes, hypertension, osteoporosis, depending on the chemical and physiological changes that occur in the living body as a result of taking it below or above the optimum value. For example; behavioral disorders occur due to malnutrition. Therefore, optimizing nutritional status can be considered a treatment method for these disorders. Nutrition plays an active role in the prevention and treatment of behavioral health disorders [5;6].

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Table 1 Nutrient substance source and effects

Carbohydrate	Depending on the consumption of more or less carbohydrate-derived nutrients; it is known to have effects on mood, depression, brain chemistry and behavior.
Protein	It is known to have effects on mood and aggression, and brain functioning due to the lack of proteins and amino acids. Also, excessive phenylalanine accumulation is known to cause brain damage and mental retardation.
Oil	The effect of an imbalance in the ratio of omega-6 and omega-3 fatty acids or a deficiency in omega-3 fatty acids on the increased depressive symptoms associated with low plasma, depression, intellectual abilities, structure and function of the brain, physicochemical, biochemical, physiological, neural and behavioral it has been reported to affect mood changes, cerebral and intellectual abilities [18;19].
Vitamin	**B-complex vitamins** It is stated that B-complex vitamins have effects on depression, mood, and behavioral characteristics in general [20].
	Vitamin B12 It is stated that Vitamin B12 affects cognitive disorders [20]. In addition, it affects depression depending on the folate level in the blood [21;22].
Mineral	**Calcium** It is known that calcium can cause depression or other mental illnesses in general.
	Chromium It is stated that chromium deficiency has effects on mental health and depression [23;24].
	Iodine Iodine has a significant effect on mental health; during pregnancy, dietary reduction of iodine has been reported to cause severe brain dysfunction and cretinism.
	Iron Iron is essential for oxygenation and energy generation in the cerebral parenchyma (via cytochrome oxidase) and for the synthesis of neurotransmitters and myelin; it is stated that there is a relationship between apathy, depression, and rapid fatigue while exercising [20]. **Lithium** Lithium; it is stated that therapeutic use with its antimanic, antidepressant and anti-suicide properties has positive effects on depression, schizoaffective disorder, aggression, impulse control disorder, and eating disorders [25].
	Selenium It is stated that there is a relationship between low selenium intake and mood, and it affects mood proportionally with selenium [26;27;28].
	Zinc It has been reported that zinc has less effect on depression in general and has an effect on antidepressant treatment [29;30]. Zinc is stated to help protect brain cells against potential damage caused by free radicals. It is also stated that deficiencies of non-essential micronutrients such as trace elements, vitamins, and polyphenols accelerate brain diseases.

One of the main roles of nutrients is their effect on the neuroendocrine system. Malnutrition affects the underlying pathology of behavioral health disorders. For example; nutrients such as tiptophane, vitamin B6, vitamin B12, folic acid (folate), phenylalanine, tyrosine, histidine, choline, and glutamic acid are necessary for the production of neurotransmitters such as serotonin, dopamine, and norepinephrine, which play a role. In contrast, poor nutritional quality leading to inadequate nutrient intake is a risk factor for the development of behavioral health disorders. It is stated that magnesium, zinc, B vitamins, vitamins such as vitamin C and vitamin E, n-3 fatty acids, amino acids (lysine and arginine), multivitamins, and mineral supplements have positive effects on anxiety disorders. Moreover; it is stated that it causes anxiety due to magnesium and zinc deficiency [7;8;9]. Zhang et al. (2013) stated that multi-vitamin and mineral supplementation reduces anxiety in type 2 diabetes patients [10]. Mazloom et al. (2013) reported that vitamin C supplements reduced anxiety in individuals with type 2 diabetes. In a study, Lakhan and Vieira (2010) stated that the amino acids L-lysine and L-arginine, which can affect the neurotransmitters related to stress and anxiety, have a positive effect [11;12]. In another study, they stated that when lysine-fortified wheat is consumed in a malnourished animal, it has significant effects on chronic anxiety and cortisol levels [13]. It is also known that vitamins C and E have positive effects on anxiety, depression, and stress. For example; generally, vitamin C is added to the waters of animals to reduce stress during transportation [11;14].

In some studies, it was observed that abnormal behaviors were exhibited due to limited nutrition and individual housing [15]. In addition, abnormal behaviors are exhibited depending on the hunger condition of the animal [16]. Sun et al. (2015) reported that the secretion of the stress hormone cortisol increased with abnormal behavior in pigs. In addition to these; autism spectrum disorder (ASD), social and communication disorders and restricted/repetitive behaviors, heterogeneous neurodevelopmental disorders, satiety, performance, restriction, repetitive behaviors, chewing behavior, and stereotypical behaviors affect animal welfare, yield and performance closely [17;18].

1.1. Behaviors observed in living things depending on Nutrition

Living exhibit innate and acquired behaviors from the moment they are born. Innate behaviors; are stereotyped movements or reflex-type behaviors that occur due to a stimulus without requiring experience. Such behaviors are passed down through generations through genes specific to the species. Many behaviors are instinctive. For example; after pregnancy, the female animal breastfeeds its young. Apart from this, it is observed that animals exhibit behaviors such as place defense, competitive behaviors, and communication in social groups. Living species exhibit various behaviors for periods that occur under the influence of illness, pain, fear, hunger, and medication. Moreover; living things exhibit abnormal behaviors such as phobia as a result of factors such as anxiety, stress, and nutrition. Chronic anxiety, nervous tension and insomnia, mood and depressive symptoms, counterconditioning and depersonalization, cognitive performance and anxiety, social interaction capacity, locomotor activity, repetitive behaviors, motor coordination and seizure sensitivity, autism spectrum disorder, alzheimer's, having antiepileptic properties, manic-type bipolar disorder, social and communication disorders and restricted/repetitive behaviors, heterogeneous neurodevelopmental disorders, satiety, performance limitation, repetitive behaviors, depression, schizophrenia, eating and anxiety disorders, attention deficit disorder/attention deficit hyperactivity disorder, impulsive and aggressive Behaviors such as eating, chewing and stereotypical are among the abnormal behaviors that occur due to feding. While exhibiting these behaviors; neurological dysfunction, neurobehavioral development, short-term spatial working memory, central nervous system, inhibition of superoxide production in blood flow, learning and memory, and secretion of the stress hormone cortisol are closely affected [1;3].

2. Discussion

Living things behave differently from species to species, depending on the situation they are in. These different behaviors are under the influence of genetic and environmental factors. Especially the effect of environmental factors has a great share [1]. Especially in studies on nutrition, which is one of the environmental factors, different model animal species have been examined. Studying pigs as model animals, Shuangbo et al. (2020) examined the effects of in vitro-in vivo feeding methods to facilitate their application in rural livestock production systems based on fiber (resistant starch and fermented soybean fiber) [31]. In the results of the study, Shuangbo et al. (2020) found that the use of 5% fiber source ratio affected increasing satiety, relieving stress, reducing abnormal behavior, and thus reducing the stillbirth rate of sows [31]. In another study, Robert et al. (2002) observed that the applied feeding restriction decreased the reproductive performance of sows by negatively affecting the secretion level of stereotypes due to increased stress during pregnancy and physical factors [25].

Studying the effects of high-fat diets during pregnancy in female mice, Zhonghai et al. (2017) examined the effects of a control diet, a high-fat diet, a folate-fortified control diet, or a folate-fortified high-fat diet for 5 weeks. In the results of the study, they reported that maternal folate supplementation helped to significantly improve behavioral disorders, cognitive performance, and anxiety-related behaviors caused by prenatal high-fat diets [33]. They also stated that BDNF and Grin2b genes are associated with methylation and expression changes. In the results of the study conducted on another model animal species, Joao et al. (2019) reported that the early stages of dairy cattle breeding, it affects social relations between animals, housing, animal welfare, behavioral and cognitive development depending on nutrition. In a study on 3xTgAd aged mice as model animals, Robert et al. (2020) reported that it affects Alzheimer's disease and low brain glucose metabolism. Moreover; in their study, they observed a positive correlation between behaviors with Pyruvate dehydrogenase (PDH), ketone ester, high concentrations of glutamate, aspartate, and n-acetyl-aspartate. They stated that there is a relationship between hippocampal n-acetyl-aspartate and avoidance behavior [32;81]. They also reported that ketosis restored citrate and α-ketoglutarate in the hippocampus of aging mice.

Niculescu et al. (2009) and Peleg-Raibstein (2012) reported that prenatal exposure to a high-fat diet has adverse effects on brain development and increases the risk of abnormal behavior related to depressive and anxious phenotypes in adulthood [34;82]. The results of the study indicate that maternal nutrition has significant effects on the regulation of several neurologically related genes in the cortex and hippocampus of the offspring, such as brain-derived neurotrophic factor 2B (BDNF) and glutamate ionotropic receptor NMDA-type subunit (Grin2b) [35;36]. Edson Luck et al. (2022) investigated the effects of Korean Red Ginseng (KRG) and valproic acid (VPA) in mouse diets. Starting at 21 days of age (P21) in the study, daily administration of oral KRG solution (100 or 200 mg/kg) to VPA-exposed mice until the end of all experiments Edson Luck et al. (2022) they did [37]. In the results of the study, Edson Luck et al. (2022) mice exposed to valproic acid (VPA) from day 28 onwards social interaction capacity (days 28 and 29), locomotor activity (days 30), repetitive behaviors (day 32), short-term spatial working memory (day 34). They stated that there were statistically significant differences in terms of motor coordination (day 36) and seizure sensitivity (28th and 38th day). Moreover; in the study, they stated that long-term CRG treatment at both dosages normalized all behaviors related to Autism spectrum disorder in VPA-exposed mice except motor coordination ability [37].

Kim et al. (2013), Kim et al. (2002), Heo et al. (2008), Lee et al. (2011) Jin et al. (1999), and Petkov and Mosharrof (1987) observed that consumption of CRF has positive effects on the central nervous system (CNS), alzheimer's, blood flow, inhibition of superoxide production, ischemic damage, learning and memory in both animals and humans [38;39;41;42;43;83]. Studying valproic acid (VPA) consumption, Davis et al. (1994) and Macritchie et al. (2001) found that it has antiepileptic properties and has a positive effect on manic-type bipolar disorder and migraine headache [40;44;45]. Davis et al. (1994), Macritchie et al. (2001), and Freitag (2002), on the other hand, stated that VPA used during pregnancy has various negative effects on embryonic development depending on the varying doses; In the human species, they reported that the offspring to be born after pregnancy is at risk of autism [40;45;46]. Rubenstein and Merzenich (2003), Kim et al. (2013), Blatt et al. (2001) and Fatemi et al. (2002) reported that VPA administered to rats with autism spectrum disorder consistently showed a decreased electroshock seizure threshold phenotype. In this situation; they determined that the stimulant/inhibitor imbalance in the brain occurs through the increase of the arousal processes and the decrease of the GABAergic receptor system [46;47;79;80]. Henzel et al. (2017) and Steenweg-de et al. (2012) reported that maternal folate deficiency in humans and animals negatively affected neurobehavioral development and psychological problems such as emotional problems emerged in the offspring [48;47]. In another study, Barua et al. (2014) reported that gestational and postnatal exposure to high concentrations of folic acid transmits impaired transcripts and cerebral gene proteins involved in normal neural development in newborn mouse pups [49].

Craciunescu et al. (2004) and Fernstrom (2000) reported that due to folic acid, affects the neocortex, which is the part of the brain responsible for neural cell proliferation, and differentiation, and complex behavior [50;51]. Moreover; researchers have stated that the effect of neurotransmitter production due to folate deficiency leads to neurological dysfunction such as behavioral and emotional changes [50;51]. Ibá ñez Talegó et al. (2011), Brousset Hernández-Jáuregui et al. (2005), Overall (1997), and Flannigan et al. (2001) stated that anxiety disorders in dogs can be caused not only by significant life changes but also by chronic or post-traumatic stresses that can alter their homeostasis and consequently lead to adjustment disorders. Moreover; typical clinical symptoms of this disorder include persistent or increased reactivity, body and environment exploration, activation, alertness, and excessive barking; they also reported that it often affects social interactions between the dog and its owner [52;53;54;55]. In another study, Serpell (1995) examined how dogs react when faced with a stimulus that causes anxiety. In the results of the study; the researcher stated that when learning how to behave when faced with a stimulus, causes counterconditioning and desensitization [56]. In studies by Riaz and Khan (2014), Das and Sarma (2014), and Overall (1997), fish proteins, rice carbohydrates, Punica granatum, Valeriana officinalis, Rosmarinus officinalis, Tilia spp, tea extract, Valeriana officinalis L-tryptophan in the diet of dogs, they stated that P. granatum was used to treat chronic anxiety, nervous tension, and insomnia [57;58;59]. In another study, Miodownik et al. (2011) and Juneija et al. (1999) reported that they observed the onset of anxiety, mood, and depressive symptoms after L-tryptophan depletion and/or an omega-3 deficiency [60;61]. Viola et al. (1994) and Coleta et al. (2001) reported that L-theanine, one of the components of tea, plays a role in reducing stress and lowering heart rate in chronic anxiety [62;63].

In another study, Hanis et al. (2020) studied the relationship between feeding and various abnormal behaviors in horses as model animals. In the study, Hanis et al. (2020) stated that oral stereotypical behaviors were most common (n = 281; 54%), followed by directed behavior (n = 181; 34%) and locomotor stereotypic behaviors (n = 63; 12%) the least [64]. In their study results, they reported that oral stereotypic behavior was significantly affected ($P < .05$) depending on the amount of straw and concentrate. Moreover; both locomotor stereotypical and directed behaviors were affected by the number of feedings per day and the amount of hay ($P < .05$) they have stated. Hothersall et al. (2009) and Sarrafchi and

Blokhuis (013) stated that concentrated feed should not be given more than roughage because it increases the risks associated with gastrointestinal dysfunction, lameness, and abnormal oral behaviors [65;66]. Jason et al. (1997) found that although it was not statistically significant in 11 different cat species as model animals, 6 out of 7 of these cats took more steps in the hour after feeding, while cats fed daily took more steps in the hour before feeding. In the results of the study, they reported that more research is needed to understand the relationship between nutrition and stereotypical behavior [67].

Ninomiya et al. (2004) examined the relationship between horses' nutrition and behavior. The results of the study suggested that the increase in feeding frequency was effective in improving the quality of life in horses due to the increase in normal active behavior such as resting behavior [68]. When studies on humans are examined, Murray and Lopez (1996) and Shabeen and Vieria (2008) stated that there is a relationship between nutritional deficiencies and physical illness; they reported that it has an effect on nutrition either on a biochemical basis or on an emotional basis [18;69]. They also stated that nutrition and behavior and emotions are intertwined. Murray and Lopez (1996) and Shabeen and Vieria (2008) reported in their studies that mental disorders, depression, bipolar disorder, schizophrenia, and obsessive-compulsive disorders especially in basic vitamins, minerals, and omega-3 fatty acids, are the most common nutritional deficiencies in humans [18;69]. They also noted that supplements containing amino acids reduce symptoms because they are converted into neurotransmitters that alleviate depression and other mental health problems [18;69]. In the studies conducted by Maurizi (1990), Hibbeln (1998), Young (2007), and Bell et al. (1991), due to the amount of omega-3 fatty acids, B vitamins, minerals, and amino acids, various psychological problems such as depression, major depression, and mental health reported causing problems [70;71;72;73]. In the results of the study conducted by Firk and Markus (2007) and Bourre (2005), they reported that amino acids tryptophan, tyrosine, phenylalanine, and methionine have positive effects on depression and mood disorders [74;75]. Brown et al. (1982) and Van (1983) stated in the results of their studies that depression was observed due to deficiencies in neurotransmitters such as serotonin, dopamine, noradrenaline, and γ-aminobutyric acid (GABA) [76;77]. In other studies, Grubb (1990) and Bell et al. (1991) stated that in addition to omega-3 fatty acids, there is a relationship between B vitamins (eg folate) and magnesium deficiencies and depression [78;73].

3. Conclusion

When the studies are examined, it is seen that there is a close relationship between nutrition and behavior in humans and various animal species. Depending on nutrition, chronic anxiety, nervous tension and insomnia, mood and depressive symptoms, counterconditioning and depersonalization, behavioral disorders, cognitive performance and anxiety, social interaction capacity, locomotor activity, repetitive behaviors, motor coordination and seizure sensitivity, autism spectrum disorder, alzheimer's disease, has antiepileptic properties, has effects on manic-type bipolar disorder and migraine headaches.

Compliance with ethical standards

Disclosure of conflict of interest

We declare that we have no competing interest as an author.

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