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ORIGINAL ARTICLE / ÖZGÜN MAKALE

ASSESSMENT OF AWARENESS AND BEHAVIORAL HABITS TO REDUCE DIETARY EXPOSURE TO MYCOTOXINS

MİKOTOKSİNLERE DİYETLE MARUZİYETİ AZALTMAK İÇİN FARKINDALIK DÜZEYİ VE DAVRANIŞSAL ALIŞKANLIKLARININ DEĞERLENDİRİLMESİ

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ABSTRACT

Objective: *Mycotoxins are known as secondary fungal metabolites that cause biochemical, physiological, and/or pathological changes in many species, including animals and plants. According to the Food and Agriculture Organization (FAO), these substances contaminate about 25% of all food in the world. Mycotoxins are responsible for many different disorders affecting the gastrointestinal, urogenital, vascular, renal, and nervous systems, as well as cancers. Key strategies for preventing and controlling exposure to mycotoxins include controlling toxin formation, implementing surveillance and monitoring programs to prevent human exposure, detoxifying the mycotoxins through biological, chemical, and physical means, and promoting dietary diversification. Although exposure cannot be avoided entirely, implementing monitoring programs is crucial to minimize it. In general, prevention of exposure to mycotoxins should receive greater emphasis. This study aims to provide information about mycotoxins and raise awareness about mycotoxin exposure.*

Material and Method: *This cross-sectional survey study was conducted with voluntary participants in Turkey between January 25, 2023-July 25, 2023, via electronic questionnaire. The questionnaire included socio-demographic data, income status, general dietary habits, frequency of consumption of mycotoxin-rich foods, knowledge about mycotoxins, and implementation of measures to prevent mycotoxin exposure.*

Result and Discussion: *A total of 796 participants (52.6% female, 46.7% male, and 0.6% other) were included in the study. This study concludes that the participants considered both the price and quality of food to be important factors. The study indicates that a high percentage of participants are unaware of the concept of mycotoxin and the associated health risk. A statistically significant change was found between whether the participants were knowledgeable about nutrition and whether they knew the concept of mycotoxin ($p<0.05$). There was a statistically significant difference*

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in participants' knowledge of healthy nutrition and knowledge of the health hazards of mycotoxins. ($p<0.05$). The results indicate a requirement for comprehensive management against mycotoxins and mycotoxin exposure, which can cause several health problems in humans.
Keywords: *Moldy foods, mycotoxins, mycotoxin exposure*

ÖZ

Amaç: *Mikotoksinler, hayvanlar ve bitkiler de dahil olmak üzere birçok türde biyokimyasal, fizyolojik ve/veya patolojik değişikliklere neden olan ikincil mantar metabolitleri olarak bilinmektedir. Gıda ve Tarım Örgütü'ne (FAO) göre, bu maddeler dünyadaki tüm gıdaların yaklaşık %25'ini kirletmektedir. Mikotoksinler gastrointestinal, ürogenital, vasküler, renal ve sinir sistemlerini etkileyen birçok farklı rahatsızlığın yanı sıra kanserlerden de sorumludur. Mikotoksinlere maruz kalmanın önlenmesi ve kontrol altına alınmasına yönelik temel stratejiler arasında toksin oluşumunun kontrol altına alınması, insanların maruz kalmasını önlemek için gözetim ve izleme programlarının uygulanması, mikotoksinlerin biyolojik, kimyasal ve fiziksel yollarla detoksifiye edilmesi ve diyet çeşitliliğinin teşvik edilmesi yer almaktadır. Maruziyet tamamen önlenemese de, izleme programlarının uygulanması maruziyeti en aza indirmek için çok önemlidir. Genel olarak, mikotoksinlere maruz kalmanın önlenmesine daha fazla önem verilmelidir. Bu çalışma, mikotoksinler hakkında bilgi vermeyi ve mikotoksin maruziyeti konusunda farkındalık yaratmayı amaçlamaktadır.*
Gereç ve Yöntem: *Bu kesitsel anket çalışması, 25 Ocak 2023-25 Temmuz 2023 tarihleri arasında Türkiye'deki gönüllü katılımcılarla elektronik anket yoluyla gerçekleştirilmiştir. Anket sosyo-demografik veriler, gelir durumu, genel beslenme alışkanlıkları, mikotoksin bakımından zengin gıdaların tüketim sıklığı, mikotoksinler hakkında bilgi ve mikotoksin maruziyetini önlemeye yönelik tedbirlerin uygulanmasını içermektedir.*
Sonuç ve Tartışma: *796 katılımcı (%52,6 kadın, %46,7 erkek ve %0,6 diğer) çalışmaya dahil edilmiştir. Bu çalışma, katılımcıların gıdanın hem fiyatını hem de kalitesini önemli faktörler olarak gördükleri sonucuna varmıştır. Çalışma, katılımcıların yüksek bir yüzdesinin mikotoksin kavramından ve buna bağlı sağlık riskinden habersiz olduğunu göstermektedir. Katılımcıların beslenme konusunda bilgili olup olmamaları ile mikotoksin kavramını bilip bilmemeleri arasında istatistiksel olarak anlamlı bir değişim bulunmuştur ($p<0.05$). Katılımcıların sağlıklı beslenme bilgisi ile mikotoksinlerin sağlığa zararları bilgisi arasında istatistiksel olarak anlamlı bir fark bulunmuştur. ($p<0.05$). Sonuçlar, insanlarda çeşitli sağlık sorunlarına neden olabilen mikotoksinlere ve mikotoksin maruziyetine karşı kapsamlı bir yönetimin gerekliliğine işaret etmektedir.*
Anahtar Kelimeler: *Küflü gıdalar, mikotoksinler, mikotoksin maruziyeti*

INTRODUCTION

Filamentous fungi synthesize mycotoxins as secondary metabolites. Mycotoxins are chemically diverse and can cause a variety of toxic effects in humans [1]. The term "mycotoxicosis" was first employed in 1952 in a study on animal diseases. The discovery of aflatoxins in the UK in 1960, following the death of 100,000 turkey poults, marked the beginning of modern mycotoxin research [2]. The term mycotoxin typically refers to the secondary metabolites of fungi, such as Aspergillus, Penicillium, Fusarium, and Clariceps, which parasitize or feed on our food crops or livestock feed [3].

These are molecules with variable structures, ranging from small heterocyclic rings that weigh up to 50 Da to larger structures, consisting of irregularly arranged 6-8 heterocyclic rings with a combined molecular weight exceeding 500 Da. [4]. Mycotoxins are found in a variety of products ranging from raw agricultural products such as corn, barley, oats, fruits, and grasses to commercial products such as aquaculture, beverages, fruit and vegetable-derived products [5].

Toxicity typically arises following ingestion, although it can also result from exposure through dermal contact or inhalation, which may lead to adverse effects. The sources and origins of fungi that produce mycotoxins are varied and, in most cases, still under investigation [6]. Mycotoxins' effects on human health depend on various factors, including their type, concentration, conjugation forms, duration of exposure, pharmacokinetics, and accumulation, ams well as the age, gender, immune system, and health status of the individual exposed to them [7]. Mycotoxins are responsible for many different

disorders affecting the gastrointestinal, urogenital, vascular, renal, and nervous systems as well as cancers [8]. Some mycotoxins weaken immunity and are therefore thought to reduce resistance to infectious diseases [9]. Exposure to mycotoxins can occur directly through the consumption of infected food and feed; humans can also be indirectly affected by consuming animals fed infected feed [10]. These toxic substances can be present in various food sources and have diverse chemical structures and various molecular mechanisms of action that impact multiple organs and systems [11]. As some fungi can generate different mycotoxins and crops can be contaminated with multiple fungal species simultaneously, several mycotoxins can often co-occur in food products. Mycotoxins that contaminate food products together can exhibit synergistic or antagonistic activities [12]. Several critical strategies for preventing and controlling exposure to mycotoxins include controlling toxin formation, implementing surveillance and monitoring programs to avoid human exposure, detoxifying through biological, chemical, and physical processes, and promoting dietary diversification.

MATERIAL AND METHOD

Questionnaire

This study was conducted between January to June of 2023 using a web-based data collection form to collect data after obtaining written informed consent from people in Turkey. Approval for the study was obtained from the Non-Interventional Clinical Research Ethics Committee of Çukurova University Non-Interventional Clinical Studies Ethics Committee (Decision Number: 68 dated 6th January 2023).

In this study, a questionnaire was created to assess the level of knowledge of mycotoxins and their exposure among participants. The questionnaire started with a section for voluntary information before moving on to the questions. The survey included questions on socio-demographic data, income status, general dietary habits, frequency of consumption of mycotoxin-rich foods, knowledge about mycotoxins, and measures taken to prevent mycotoxin exposure.

Statistical Analysis

Data evaluation was conducted using SPSS 20.0. Descriptive analysis involved the use of frequency, percentage, mean, and standard deviation values. We analyzed the data for normality and then used t-tests for independent groups in comparisons of two groups, and One-Way ANOVA for comparisons of more than two groups. We also conducted cross-tabulations and chi-square statistics. We considered *p*-values of 0.05 or less as statistically significant in all tests.

RESULT AND DISCUSSION

Demographic Data

The sample of the study consisted of 796 volunteer participants. Table 1 displays the sociodemographic characteristics of the participants.

The average age of the individuals who participated in the study was 28.51±2.67. 52.6% of the participants were female and 46.7% were male. A large number of the individuals participating in the survey (18.7%) stated that their economic income was between 10 thousand and 15 thousand TL. The educational status of the participants was distributed as primary school (1.8%) secondary school (2.4%) and high school (16.5%) university (70.5%) master's degree (6.5%) doctorate (2%).

Descriptive Statistical Analysis of Participants' Dietary Habits

When the diet types of the participants were analyzed, it was observed that the rate of omnivorous was (95%) (Table 2).

The places where participants prefer to eat were questioned. It is observed that the majority of individuals (85.9%) prefer to eat at home (Table 3).

Participants were asked whether they considered themselves to have sufficient knowledge about healthy nutrition. 57.4% of the participants stated that they did not have enough knowledge about nutrition and 33.7% stated that they had enough knowledge.

The participants' opinions on the quality and price of food were evaluated. It can be concluded that for the majority of participants (58.3%), the quality of food (45.2%) and the price of food (45.2%) are very important.

Table 1. Demographic data

		Frequency (n)	Percentage (%)
Gender			
	Female	419	52.6
	Male	372	46.7
	Participants who do not specify gender	5	.6
Education Status			
	No formal education	3	.4
	Primary School	14	1.8
	Middle School	19	2.4
	High School	131	16.5
	University	561	70.5
	Master's Degree	52	6.5
	PhD	16	2.0
Monthly income	No monthly income	191	24.0
	0 - 2.000 TL	99	12.4
	2.000-5.500 TL	93	11.7
	5.500 - 10.000 TL	120	15.1
	10.000 - 15.000 TL	149	18.7
	15.000-20.000 TL	58	7.3
	20.000- 25.000 TL	19	2.4
	25.000 - 30.000 TL	12	1.5
	30.000-35.000 TL	2	.3
	35.000TL and above	18	2.3
	Not want to specify	35	4.4

Table 2. Diet types

What type of diet do you prefer?				
	Frequency	**Percent**	**Percent**	**Cumulative Percent**
Vegan	20	2.5	2.5	2.5
Vegetarian	17	2.1	2.1	4.6
Omnivorous	759	95.4	95.4	100.0

Table 3. Dining venue preferences

		Frequency (n)	Percentage (%)
Dining venue preferences	Home	684	85.9
	Cafe/Restaurant	112	14.1

The frequency with which participants consume different foods was analyzed. Spices (57.9%) and coffee (46.5%) have the highest daily consumption rates. These were followed by bakery products, fruit, and dairy products (Figure 1).

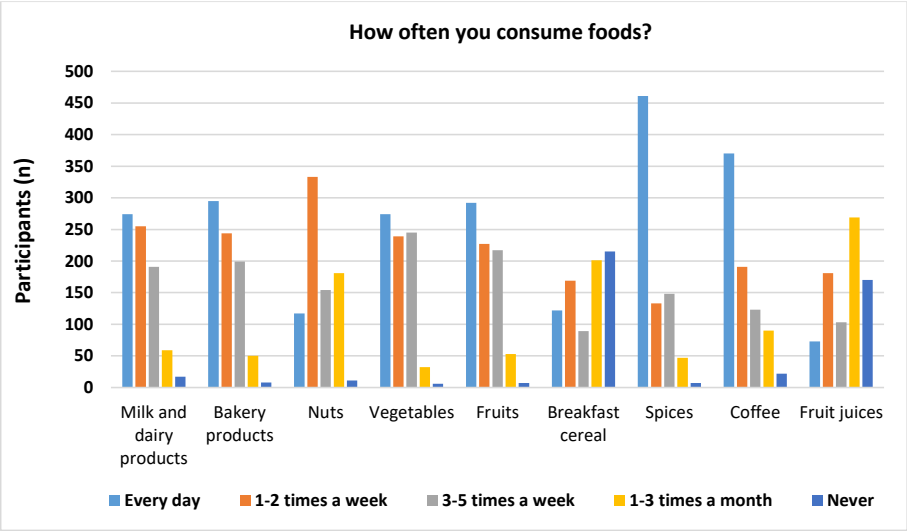

Figure 1. Daily consumption rates of foods

Descriptive Statistical Analysis of Participants' Mycotoxin Awareness and Healthy Consumption of Foods

In this study, we aimed to measure the mycotoxin awareness of the participants and the questions they were asked and the response patterns are given in Table 4.

Table 4. Descriptive statistics

		Frequency (n)	Percentage (%)
I have heard of mycotoxin before	Yes	210	26.4
	No	586	73.6
I know the health hazards of mycotoxins	Yes	135	17.0
	No	541	68.0
	Partily	120	15.1
I buy food as fresh as possible and consume it in a short time	Strongly disagree	45	5.7
	Disagree	61	77
	Partially agree	65	8.2
	I agree	312	39.2
	Completely agree	313	39.3
I store food in a clean, dry, and cool place	Strongly disagree	37	4.6
	Disagree	64	8.0
	Partially agree	42	5.3
	I agree	315	39.6
	Completely agree	338	42.5
I clean areas such as the refrigerator and pantry once a week	Strongly disagree	53	6.7
	Disagree	122	15.3
	Partially agree	189	23.7
	I agree	249	31.3
	Completely agree	183	23.0
I throw away moldy food immediately	Strongly disagree	37	4.6
	Disagree	72	9.0
	Partially agree	60	7.5
	I agree	188	23.6
	Completely agree	439	55.2

Table 4 (*continue*). Descriptive statistics

		Frequency (n)	Percentage (%)
I do not consume spoiled milk and dairy products	Strongly disagree	44	5.5
	Disagree	56	7.0
	Partially agree	21	2.6
	I agree	155	19.5
	Completely agree	520	65.3
I store cereals and flour in a dry place	Strongly disagree	44	5.5
	Disagree	55	6.9
	Partially agree	38	4.8
	I agree	225	28.3
	Completely agree	434	54.5
I buy fruit and vegetables that are as intact as possible, not injured or dented	Strongly disagree	38	4.8
	Disagree	70	8.8
	Partially agree	38	4.8
	I agree	221	27.8
	completely agree	429	53.9
I don't eat rotting fruit, I don't make compotes and jams	Strongly disagree	51	6.4
	Disagree	86	10.8
	Partially agree	79	9.9
	I agree	201	25.3
	Completely agree	379	47.6
Even if there is mold on a piece of bread, I throw it away whole	Strongly disagree	74	9.3
	Disagree	109	13.7
	Partially agree	97	12.2
	I agree	196	24.6
	Completely agree	320	40.2
I throw away meat or sausage when it gets moldy	Strongly disagree	39	4.9
	Disagree	68	8.5
	Partially agree	32	4.0
	I agree	177	22.2
	Completely agree	480	60.3
I don't consume moldy nuts, I throw them away when they are moldy	Strongly disagree	38	4.8
	Disagree	63	7.9
	Partially agree	31	3.9
	I agree	184	23.1
	Completely agree	480	60.3
I buy spices in small quantities and consume them quickly	Strongly disagree	73	9.2
	Disagree	114	14.3
	Partially agree	145	18.2
	I agree	230	28.9
	Completely agree	234	29.4
I don't give moldy food to animals	Strongly disagree	68	8.5
	Disagree	84	10.6
	Partially agree	62	7.8
	I agree	171	21.5
	Completely agree	411	51.6

A comparison of the responses of the participants to the questions in Table 4 with all of the responses. There is a statistically significant difference ($p<0.05$) in whether or not participants consume

moldy foods depending on their gender. Female participants use moldy foods 372 (46.7%) less than male individuals 419 (52.6%).

The analysis was performed on the consumption of moldy foods according to the diet types of the participants. There was a statistically significant difference ($p<0.05$) in the consumption of moldy foods according to the participants' diet types. Individuals with vegetarian and vegan diets consumed significantly less moldy foods than those with omnivorous diets. A statistically significant difference was found between whether the participants were knowledgeable about healthy eating and whether they knew the concept of mycotoxins ($p<0.05$). Participants who were knowledgeable about healthy eating had a higher rate of having heard of the concept of mycotoxins.

A statistically significant difference ($p<0.05$) has been found between the answers of the participants regarding the consumption of moldy food and their knowledge about healthy nutrition. 29.9% of the participants who think that they are knowledgeable about nutrition do not consume food that has started to turn moldy. Among the participants who did not think they were knowledgeable about nutrition, 50.3% did not consume food that had started to turn moldy.

The answers of the participants to the question "I do not eat rotten fruits and do not make jam from them" have a statistically significant change according to their monthly income level ($p<0.05$). While 45.1% of the participants with an income level of 20 thousand TL and below answered that they completely agree with the question, 2.5% of the participants with an income level of 20 thousand TL and above answered that they completely agree with the question. There is a statistically significant difference ($p<0.05$) between whether or not participants are aware that moldy food can pose a risk to their health, depending on how much importance participants attach to food quality. It can be seen that participants who are aware of the risk also attach importance to quality. A comparative analysis of the income level of the participants and their knowledge of the health hazards of mycotoxins was performed. No statistically significant change was found ($p>0.05$).

An estimated 500 million people, mostly living in rural areas, are exposed to precarious levels of mycotoxins, according to the World Health Organization. Several factors promote frequent contamination of food crops by mycotoxigenic fungi, leading to the alarming statistic mentioned above. These factors include climatic conditions, poor agricultural practices, poverty, inadequate knowledge about mycotoxins among primary food producers, and a lack of mycotoxin regulations [13].

The study conducted in two north-central Nigerian states reports a comprehensive overview of multiple mycotoxin contamination of various foods consumed by households, including cereals, nuts, and legumes. At least 80% of the respondents in each state (Nasarawa: 84%; Niger: 80%) indicated the ability to identify molds in foods and stored grains by discoloration of food items. However, only 43% and 15% of the respondents from Nasarawa and Niger states, respectively, were aware of what mycotoxins are, and only 26% and 11% of respondents, respectively, were aware of possible food handling practices to reduce mycotoxin contamination in food [14]. In our study, the frequency of those who consumed foods that started to mold was 2.8% and the frequency of those who had heard of mycotoxins was 26.4%. In addition, the frequency of people who were aware of the health hazards of mycotoxins was determined as 68%.

A study conducted in southwestern Nigeria assessed the perceived attitudes, practices, and knowledge of fermented food vendors regarding fungal colonization of foodstuffs, a precursor to mycotoxins. The result shows a wide knowledge gap among those surveyed ($n = 86$), as 98% were unable to link fungi to mycotoxin contamination and perceived associated health risks. A significant number of people in both developed and developing countries are poorly informed about contaminants in food. The majority of participants (93%) were women. Few participants had no formal education (11%), while most of those who did have a primary education (61%). Mycotoxins are at the forefront of chronic food toxicants, usually occurring below levels that cause acute health effects, but such levels can cause long-term health effects among humans and animals. It can therefore be difficult to link various health complications to mycotoxin exposure, which strongly supports the poor perception of respondents in the Nigerian study on the issue. That study provided insights into the safety of fermented foods produced in Nigeria and likewise raised vendors' awareness of fungal and mycotoxin contamination and associated health risks. It was observed that there was a wide knowledge gap among the respondents regarding this aspect of food safety [15]. In our study, there was a wide knowledge gap

among the respondents, as 26.4% had heard of mycotoxins, 46.7% of the respondents in our study were male and 52.6% were female. Very few of the participants in our study had no formal education (0.4), whereas most of those who had education had a university education (70.5%). Our study provided us with information about mycotoxin exposure and awareness among people living in Turkey.

A study conducted in Belgium showed that around 70% of the participants believed mycotoxins have the potential to cause toxicity in humans or animals. Consumers, in general, lack knowledge about mycotoxins as biohazards [16].

In a study conducted in Germany, an online questionnaire was administered to a cohort of university students (n=186) to investigate knowledge about mycotoxins and adherence to behavioral practices or habits that may influence the risk of mycotoxin exposure. The results of the study indicate an overall rather low level of knowledge about mycotoxins in the studied cohort and a poor perception of the risks associated with them compared to similar studies; about half of the group was not familiar with the term "mycotoxin". In the German study, 54% of respondents indicated familiarity with mold toxins and 48% of all respondents answered yes to the question "Have you ever heard the term mycotoxin?". In general, the health risks of mycotoxins ranged from "quite risky" to "extremely risky". Similarly, 55% of respondents indicated that they were "concerned" or "very concerned" about the presence of mycotoxins in food. Following an intervention text, 64% of respondents answered that they were already aware of the health hazards caused by mold toxins in food. Consequently, mycotoxin prevention strategies should not stop at the retail level; in particular, disclosure and information on health risks from mycotoxins are recommended to reduce the risk of exposure in private households or informal trade markets [17]. In our study, an electronic questionnaire was administered to 796 volunteers. As a result of the survey, the prevalence of those who did not consume moldy foods was 87.1%. The frequency of people who thought they were knowledgeable about nutrition was 33.7%. There was a statistically significant difference between the participants' knowledge of nutrition and their knowledge of mycotoxin ($p=0.000$). As a result of our study, it is concluded that people have not heard of the concept of mycotoxin before and do not know the health hazards of mycotoxins.

The variation in consumer food safety knowledge and practices across demographic categories and possibly socioeconomic, educational, and cultural levels [18] could account for the differences in knowledge and awareness levels observed between our study group and previously published studies.

In conclusion, as a result of this study, it is concluded that volunteer individuals have not heard of the concept of mycotoxin before and do not know the health hazards of mycotoxins sufficiently.

It is an undeniable fact that individuals attach importance to both the quality and price of food.

According to the gender of the participants, whether they consume moldy foods or not varies statistically significantly ($p<0.05$).

A statistically significant change was found between whether the participants were knowledgeable about nutrition and whether they knew the concept of mycotoxin ($p<0.05$). According to these results, there is a need for comprehensive management against mycotoxins and mycotoxin exposure, which pose many problems for human health. Therefore, necessary plans should be made by the relevant organizations to raise awareness about mycotoxin hazards and exposure.

AUTHOR CONTRIBUTIONS

Concept: G.D.; Design: G.D.; Control: G.D.; Sources: G.D., N.N.D.; Materials: G.D., N.N.D.; Data Collection and/or Processing: G.D., N.N.D.; Analysis and/or Interpretation: G.D., N.N.D.; Literature Review: N.N.D.; Manuscript Writing: G.D.; Critical Review: G.D.; Other: -

CONFLICT OF INTEREST

The authors declare that there is no real, potential, or perceived conflict of interest for this article.

ETHICS COMMITTEE APPROVAL

All procedure was approved by the Non-Interventional Clinical Research Ethics Committee of Çukurova University Non-Interventional Clinical Studies Ethics Committee (Decision Number: 68

dated 6th January 2023).

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