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ASSESSMENT OF LONG-TERM TASTE AND SMELL COLOR BLINDNESS AS A RESULT OF COVID-19 DISEASE

Among the effects of COVID-19 are taste and smell disorders, which have occurred in a significant number of sick people. It is believed that the impairment of these senses may be long term. The aim of our research was to investigate the impact of COVID-19 disease on the ability to recognize tastes among students at the Rzeszów University of Technology. The research was conducted on a sample of students who declared that they had or had not suffered from COVID-19. The assessment of the ability to recognize flavors – that is, taste color blindness – was carried out based on the methodology recommended by the Polish Committee for Standardization [PN ISO3972]. The research, which involved 68 women and 74 men, was carried out in a laboratory adapted for this purpose, meeting the requirements specified in the standard [PN ISO 8589]. The tests took place in the morning (9 a.m.––12 p.m.). Taste recognition ability was assessed using a set of aqueous solutions of citric acid (0.43 g/L), sucrose (5.76 g/L), sodium chloride (1.19 g/L) and caffeine (0.195 g/L). The collected questionnaires were based on a standard approach to food quality analysis, and the data obtained were analyzed in the Statistica 13.3 program. It was observed that, in the studied group of students, the percentage of people who declared COVID-19 disease was high (69%). In this group, the majority of respondents (51%) described the course of the disease as mild. Among the respondents, 63.3% indicated a loss of taste, while slightly more (69.4%) declared a loss of smell. The analysis of data regarding the ability to correctly recognize individual tastes indicates that gender influenced the ability to recognize sweet and bitter tastes. Statistically, significantly more men misidentified these flavors. The impact of

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COVID-19 infection on the ability to identify the analyzed flavors was moderate and was confirmed only for salty and bitter tastes. Therefore, the ability to perceive important qualitative factors of food products was impaired.

Keywords: students at the Rzeszow University of Technology, COVID-19, life quality, smell loss, taste loss, taste daltonism.

1. INTRODUCTION

The virus responsible for COVID-19 disease, SARS-CoV-2, was first time detected as a novel member of the coronavirus family in China in 2019. The contagious disease rapidly became a pandemic on the world encompassing scale. It is known that this virus can cause severe respiratory failure and even death in infected patients (Al-Swiahb et al., 2021, Saraf et al., 2023, Song et al., 2021).

The most common symptoms of COVID-19 are fever, cough, and fatigue. Other common symptoms include shortness of breath, body aches, sore throat, headache, chills, and nasal congestion. In some cases, people with COVID-19 may also experience diarrhoea, nausea, or vomiting. In addition, ear, nose, and throat symptoms, including loss of sense of smell and/or loss of sense of taste have been reported as symptoms caused by this virus (Coelho et al., 2021; Klopfenstein et al., 2020; Męczykowska et al., 2020). In the peer-reviewed medical literature, it has been reported that infection with SARS-CoV-2 in cases of some patients may cause smell and/or loss of sense of taste without nasal discharge and, unlike other viruses that infect the upper respiratory tract. It is important to note that not everyone with COVID-19 will experience symptoms, and some people may have mild or no symptoms at all. There is a number of contrary behaviour of SARS-CoV-2 between various patients (Barón-Sánchez et al., 2020; Klinger et al., 2020; Sakalli et al., 2020). The loss of smell and taste, also known as anosmia (Loss of sense of smell) and ageusia (loss of sense of taste), respectively, occurs in a significant proportion of COVID-19-19 patients, even in those cases where patients show no other symptoms (Klinger et al., 2020). The loss of smell and taste is thought to be caused by the virus damaging the olfactory nerve and its associated cells, which are responsible for detecting smells (Butowt et al., 2023; Karamali et al., 2022; Xydakis et al., 2021).

Studies are underway to investigate the biological mechanisms behind COVID-19-related anosmia and to uncover treatments to address post-COVID-19 smell dysfunction (Dolgin 2022; Husain et al., 2021), but it is believed to involve the disruption of neural pathways and the impairment of the cells responsible for detecting and transmitting smells and tastes (Scotto et al., 2022). Congestion and swelling of the nasal passages due to the infection can interfere with the detection of smells (Xu et al., 2022). While the loss of smell and taste is generally temporary and resolves within a few weeks in most cases, some patients may experience long-term or even permanent changes in their ability to taste and smell (Kumar et al., 2021). In addition, the loss of smell and taste can have a significant impact on a person's quality of life, affecting their ability to enjoy food and beverages, detect dangerous odours, and identify spoiled or contaminated food.

In this manuscript a statistic assay was utilized in order to analyse the percentage of cases of smell and taste losses as a result of COVID-19 infections among students of Rzeszów University of Technology. The conducted research aimed the determination of adverse effects of the infection on smell and taste senses and therefore the quality life determined by the lack or presence of features of consumed food products.

2. MATERIALS AND METHODS

The current study was conducted in the spring of 2023 in Rzeszów, involving 142 students from the Faculty of Management at Rzeszów University of Technology. All participants agreed upon to report and completed a survey providing information regarding, among other things: gender (male, female), place of residence (village, city up to 100,000 inhabitants, city over 100,000 inhabitants), financial situation (average, good, very good), eating habits (proper, improper, unsure), COVID-19 infection, course of the disease, and whether the disease was accompanied by a loss of taste and/or smell. A specially prepared questionnaire also allowed for the evaluation of the healthy dietary habits of the study participants. The assessment of taste recognition ability and taste colour blindness was conducted based on the methodology recommended by the Polish Committee for Standardization PN ISO3972. The study, in which 68 women and 74 men participated, was carried out in a laboratory adapted for this purpose, aiming to provide conditions as prescribed by the standard methodology PN ISO 8589. The research took place in the morning hours (9–12). Based on declarations, the participants abstained from alcohol and strongly flavoured or aromatic foods on the day before the study. On the day of the study, they consumed a light meal, and 90 minutes before the study, they refrained from eating, drinking, and smoking. The taste recognition ability was assessed using a set of aqueous solutions of citric acid (0.43 g/L), sucrose (5.76 g/L), sodium chloride (1.19 g/L), and caffeine (0.195 g/L). The taste samples, at a temperature of approximately 20°C, were served in 40 ml labelled glass containers. The taste samples were examined unhurriedly, with approximately 20 ml of the solution taken into the mouth at a time. Before each sample, the oral cavity was rinsed with water at approximately 20°C. The test results were recorded in sheets. The obtained results underwent statistical analysis using the Statistica 13.3 software. All dependencies and correlations were verified using the chi-square independence test, with a significance level set at $\alpha = 0.05$.

The research was based on the questionnaires filled by the students as part of food industry technology course with additional questions about the COVID-19 related observations. Therefore the analysis of flavours and smells took place as part of classes on sensory analysis of food as part of the mandatory food industry technology course in the field of logistics studies. As such it was obligatory to utilize well known methods for determination of food parameters. The utilized substances, that played the role of the taste and smell determinants were not of hazardous nature. Therefore the authors did not seek an opinion of ethics committee on the research on humans. The research participants agreed on the studies conditions, and the research was introduced as a part of standard course witch the students agreed upon as a part of their study.

3. RESULTS AND DISCUSSION

In the Table 1 the Socio-demographic characteristics of the respondents in the group of students of Rzeszow University of Technology was provided. In the table 1 various characteristics such as gender and economic status and nutrition habits of students that took part in the research.

Within the experiment a slightly higher amount of male respondents took part (52,1% of respondents). Close to equal distribution of gender of respondents can be considered as an important argument with positive impact on the creditability of conducted research. In particular the even distribution of gender factor allows for statistically significant results of the conducted scientific investigation.

This corresponds with distribution of human species gender in nature which is in general close to even. As a conclusion drawn from the analysis of the earlier results of other researchers in some cases the distribution of gender of respondents was often uneven. Such observation were reported mainly based on the research by Zborowski and Mikulec (Zborowski et al., 2021). In their research the majority of respondents were females who were responsible for 74% of results based on the investigated population. Female students were also more likely to participate in long-term studies of veterinary students, constituting over 60% of the study population. Undoubtedly, in the case of the gender structure in research conducted with students, the profile of the university and the field of study of the respondents are important.

The data concerning characteristics of the group of students asked about the loss of smell and taste as a result of the infection with the COVID-19 disease are presented in Table 1.

Table 1. Socio-demographic characteristics of study participants

Factor	Factor catygory	n	%
Gender	Man	74	52.1
	Woman	68	47.9
Place of living	Village	82	57.7
	City up to 100,000	40	28.2
	City over 100 thousand	20	14.1
Economic status	Average	24	16.9
	good	100	70.4
	Very good	18	12.7
Nutrition	proper	82	57.7
	Improper	30	21.1
	unsure	28	19.7
Number of meals eaten	1	10	7.0
	2	40	28.2
	3	68	47.9
	4	22	15.5

Source: authors' own research.

Most source studies show that surveyed students and young people most often declare eating 3 or 4 meals a day, while the share of people who eat a larger number of meals concerns 5–15% of respondents. Similarly, in our own research, most research participants declared that they ate 3 meals a day. The share of these people in the study group is 47.9% (Table 1). A relatively large number of people, 28.2%, declared that they ate only 2 meals a day. At the same time, it should be noted that, according to other authors, the outbreak of the COVID-19 pandemic, and especially the period of quarantine and isolation, caused isolated people to tend to eat more meals.

In the authors' own research, respondents were asked to provide information regarding the incidence and course of COVID-19 disease. The survey results were summarized in Table 2.

Table 2. Infections, course of illness, symptoms of COVID-19 infection of study participants

Factor	Factor catygory	n	%
Was sick	No	44	31.0
	Yes	98	69.0
Test confirmation	No	62	63.3
	Yes	36	36.7
Course of illness	Mild	50	51.0
	Moderate	42	42.9
	Sever	6	6.1
Loss of taste	No	36	36.7
	Yes	62	63.3
Loss of smell	No	30	30.6
	Yes	68	69.4

Source: authors' own research.

The answers to the question about the incidence of COWID-19 show that a total of up to 69% of the surveyed students were ill. The infection rate determined in our own research was much higher compared to the results obtained by (Zborowski et al., 2021), in which approximately 20% indicated the risk of Covid-19, while the share of people answering "I don't know" in these studies was approximately 37% (Mikulec et al., 2022).

Further analysis of the course of COVID-19 infection shows that relatively few people confirmed the disease by performing an appropriate test. This means that the majority (63.3%) of respondents identified OVID-19 infection only with the occurrence of somatic symptoms typical of this disease (Table 2). At the same time, only 6.1% of the surveyed respondents declared that the disease was severe.

According (Zawilska et al., 2021), approximately 72% of people infected with SARS--CoV-2 have asymptomatic or minimally symptomatic disease, 8% have mild symptoms, and approximately 14% of patients have severe symptoms requiring hospitalization.

The main aim of the presented research was the assessment of the taste blindness of students of the Rzeszów University of Technology. The research results are based on the correct identification of four basic tastes and were prepared in accordance with the guidelines provided in Polish standards and by (Masłowska et al., 2010).

Tables 3–6 provides information on statistically analysed answers for questionnaires filled by respondents from the group of students of Rzeszow University of Technology. Each table provides insight into the structure of correct and incorrect identification of salty, sweet, acidic and bitter tastes depending on gender, the infections and course of COVID-19 of study participants.

All dependencies and interdependencies were verified using the chi-square test of independence, with a predetermined significance level $\alpha = 0.05$. The decision to reject the null hypothesis was based on the test probability level (p). The null hypothesis was rejected when the test probability level was lower than or equal to 0.05.Statistica 13.3 software package was used for the analysis.

The analysis of the results regarding the influence of gender on the correct identification of the tested tastes did not reveal any statistically significant impact of this factor on the recognition of salty, sweet and sour tastes (Tables 3–5).

Table 3. The structure of false and correct identification of salty taste by group of respondents depending of gender, infection and course of COVID-19 illness of research participants

Factor	Factor catygory	Salty Taste		p-value
		Percentage of identifications		
		False	Correct	
Sex	Man	45.95%	54.05%	0,352
	Woman	38.24%	61.76%	
Was sick	No	40.91%	59.09%	0,828
	Yes	42.86%	57.14%	
Loss of taste	No	44.44%	55.56%	0,809
	Yes	41.94%	58.06%	
Loss of smell	No	33.33%	66,67%	**0,048**
	Yes	**49.06%**	50.94%	
Curse of the sicknes	Mild	32.00%	68.00%	**0,027**
	Moderate/sever	54.17%	45.83%	

Source: authors' own research.

Table 3 presents the results regarding the structure of salty taste identification by research participants. The analysis of the data contained in the table shows that people who declared a loss of smell made statistically significantly more incorrect identifications of salty taste (Table 3). It was also shown that the ability to identify this taste depended on the course of the disease. People with moderate and severe COVID-19 incorrectly identified salty taste in over 50% of cases, while the share of people with mild COVID-19 was 32%. (Table 3).

Table 4. The structure of false and correct identification of sweet taste by group of respondents depending of gender, infection and course of COVID-19 illness of research participants

Factor	Factor catygory	Sweet Taste		p-value
		Percentage of identifications		
		False	Correct	
Sex	Man	**45.95%**	54.05%	**0,042**
	Woman	28.35%	71.65%	
Was sick	No	31.82%	68.18%	0,213
	Yes	42.86%	57.14%	
Loss of taste	No	38.89%	61.11%	0,545
	Yes	45.16%	54.84%	
Loss of smell	No	40.00%	60.00%	0,704
	Yes	44.12%	55.88%	
Curse of the sicknes	Mild	44.00%	56.00%	0,816
	Moderate/sever	41.67%	58.33%	

Source: authors' own research.

Analysis of the data summarized in Table 4 showed that men made a statistically significantly higher percentage of incorrect answers. It is worth emphasizing that the share of those giving incorrect answers regarding the identification of sweet taste was almost twice as high compared to the share of women (Table 4). It was also established that the course of the disease and the loss of the senses of taste and smell did not significantly affect the perception of sweet taste by the study participants.

In turn, according to research carried out by (Gomółka-Pawlicka et al., 2018), women recognized individual tastes better than men, and particularly clear differences concerned the recognition of salty and sour tastes. Women's predisposition to correctly identify sour taste was also confirmed in our own research (Table 5). It was found that over 91% of the surveyed women correctly identified this stimulus, while the percentage of men who correctly identified the sour taste was 83.78%. It is also worth noting that the incidence of COVID-19 did not significantly affect the ability to identify sour taste. The percentage of respondents who correctly identified themselves was almost the same in the group of people who had and did not suffer from COVID-19.

Table 5. The structure of false and correct identification of acidic taste by group of respondents depending of gender, infection and course of COVID-19 illness of research participants

Factor	Factor catygory	Acidic Taste		p-value
		Percentage of identifications		
		False	Correct	
Sex	Man	16.22%	83.78%	0,186
	Woman	8.82%	91.18%	
Was sick	No	13.64%	86.36%	0,818
	Yes	12.24%	87.76%	
Loss of taste	No	16.67%	83.33%	0,309
	Yes	9.68%	90.32%	
Loss of smell	No	**13.33%**	86.67%	0,287
	Yes	2.94%	97.06%	
Curse of the sicknes	Mild	16.00%	84.00%	0,247
	Moderate/sever	8.33%	91.67%	

Source: authors' own research.

Only gender differentiated the ability to identify bitter taste (Table 6). It was also found that statistically significantly more women (67.71%) correctly identified this sensory stimulus, while only 48.66% of men correctly indicated this taste, which is almost 20% less than in the case of women.

In the case of sweet and bitter taste the man showed a statistical significant higher percentage of false identification of taste than woman. In the case of COVID-19 disease as the result of infection the false result of taste identification occurred at the statistical significant level only in case of bitter taste, (salty, sweet and acidic taste were characterized by to low statistical significance. Next the share of incorrect indications of the assessed tastes depending on the impact of the taste loss symptom in the subjects was summarized. The observed differences were not statistical significant. Another observation was that in

case of salty and bitter taste the percentage of incorrect identifications of taste was dependent on the reported loss of sense of smell. During the course of COVID-19 infection in case of mild symptoms of disease it was revealed that the illness had no result on the increase of false identification of all from the chosen taste cases. However as a result of moderate or severe symptoms the illness resulted in the statistical significant loss of salty taste. In the case of gender susceptibility to taste lose it was observed that woman showed higher resistance to the negative result of the COVID-19 illness in the case of taste loss. Over 41% of woman were able to identify all four of the investigated tastes. In the group of male respondents only a quarter of students identified correctly all four tastes. In the case of people questioned about the taste lose in the course of COVID-19 illness it was revealed that the majority of students did not correctly identified all four tastes. The course of COVID-19 disease had no impact on the number of correct identification of tastes.

Table 6. The structure of false and correct identification of bitter taste by group of respondents depending of gender, infection and course of COVID-19 illness of research participants

Factor	Factor catygory	Bitter Taste		p-value
		Percentage of identifications		
		False	Correct	
Sex	Man	**51.35%**	48.65%	**0,033**
	Woman	32.29%	67.71%	
Was sick	No	31.82%	68.18%	**0,048**
	Yes	**48.98%**	51.02%	
Loss of taste	No	38.89%	61.11%	0,128
	Yes	54.84%	45.16%	
Loss of smell	No	30.00%	70.00%	**0,037**
	Yes	**52.94%**	47.06%	
Curse of the sicknes	Mild	48.00%	52.00%	0,843
	Moderate/sever	50.00%	50.00%	

Source: authors' own research.

To sum up, the results of the questionary of the students of Rzeszow University of Technology, revealed following data; test probability values lower than the adopted significance level indicate statistically significant dependencies on: gender (a higher percentage of men correctly identified at most one taste type; a higher percentage of women correctly identified all four taste types). Past illness (a higher percentage of individuals with an illness correctly identified at most one taste type; a higher percentage of individuals without an illness correctly identified all four taste types). Loss of taste (a higher percentage of those who have lost their sense of taste correctly identified only two taste types; a higher percentage of those who have not lost their sense of taste correctly identified three or four taste types) (Tables 3–6). Loss of sense of smell (a higher percentage of those who have lost their sense of smell correctly identified only two taste types; a higher percentage of those who have not lost their sense of smell correctly identified four taste types). In general in the case of bitter taste – the impact of gender was statistical significant and the higher percentage of incorrect identifications were in the group of men. Also in case of bitter taste

– there was a statistical significant impact of illness. There the higher percentage of incorrect identifications in the group of individuals with a history of illness was recorded. Moreover in the case of bitter taste the loss of sense of smell was also identified as a factor with impact on other sense (higher percentage of incorrect taste identifications in the group of people who have lost their sense of smell).

In the remaining cases (course of illness), no statistically significant dependency was found ($p>0.05$) (Tables 3–6).

According to earlier related research by (Szczawiński et al. 2017), The students of Warsaw university were tested on smell and taste identification. The results were subjected to statistical analysis. There it was shown that female students were more likely to correctly identify the investigated features of food products (Tables 3–6). Furthermore as the time passed new generation of students were identified to be more accurate in determining the food features such as smell and taste. This trend can be stopped by the long-time effects of COVID-19 illness.

In general the patients infected with SARS-CoV-2 exhibited various and wide range of symptoms. In Asia, 85.6% of patients had fever, 68.7% had cough, and 39.4% had fatigue as the main symptoms determined at the treatment stage. Furthermore nasal congestion, and sore throat may be, an additional problems reported by patients infected with SARS-CoV-2. Meanwhile in Europe in particular in Italy, the most common symptoms were fever (55.9%), cough (60.4%), and fatigue (68.3%) (Sakalli et al., 2020).

Based on the data obtained with the COVID-19 Anosmia Reporting Tool developed in USA it was indicated that 73% of 237 SARS-CoV-2-positive patients had experienced loss of sense of smell at admission to hospital. In other study that was conducted in 417 SARS-CoV-2-positive patients with mild or moderate symptoms, 85.6% of patients described loss of sense of smell, 88.8% described loss of taste, and 79.6% of those with loss of sense of smell had anosmia and 78.4% reported that they had ageusia. Based on this and other data, the loss of smell was agreed upon to be referenced as a valid marker of COVID-19 disease (Marchese-Ragona et al., 2020).

Some of the reviewed manuscripts contain research on the topic of the prevalence and mechanisms of olfactory and gustatory dysfunction (OGD) in COVID-19 patients. Anosmia and OGD have been reported as distinguishing symptoms of COVID-19, with a high prevalence observed in patients. These symptoms have been included in official lists of COVID-19-19 symptoms (Shahzaib et al., 2022). Although the importance of the various symptoms for identification of ongoing illness was more important in the past, the long term results of the infection are of interest since the disease show some long lasting effects affecting the quality of life (Coelho et al., 2021).

Both the central and peripheral nervous systems are believed to be impacted by the virus, with evidence of neuroinvasion, expression of ACE-2 receptors in neurons and glial cells, and the presence of the virus in cerebrospinal fluid. Sialic acid receptors, involved in taste perception, may also be bound by the virus, potentially increasing the gustatory threshold. OGD may occur simultaneously without one symptom dominating, and taste disorders are unlikely to exist in isolation (Scotto et al., 2022).

The immune response and subsequent inflammation in patients with robust immune systems may lead to degeneration of olfactory neurons, causing smell dysfunction, while weaker immune responses spare the nasal mucosa. Although objective and subjective assessment of OGD could be utilized in order to help in primary screening, considering the constraints of PCR testing on medical resources, the aim of authors research was to estimate the long term effect of COVID-19 disease on the quality of life related to loss of

smell and taste senses. From long-term research conducted by (Szczawiński et al. 2017), conclusions can be drawn that approximately 34% of veterinary students may have some difficulties with the recognition of tastes and smells, which, according to the authors, may be a limitation in the employment of food assessment inspectors. Also this results in negative effect on the life quality of infected people. Furthermore as a result of COVID-19 it was observed that in the group of sick people the respondents tend to eat more and drink more alcohol which caused increase of body weight (Mikulec et al., 2022; Sidor et al., 2020).

4. CONCLUSION

1. In the surveyed group of students, the share of people who declared Covid-19 disease was high and amounted to 69%. Within this group, the majority of respondents (51%) declared the course of the disease to be mild.
2. Among the respondents, 63.3% of the participants indicated a loss of taste, while slightly more 69.4% of the participants declared a loss of smell.
3. The analysis of data regarding the ability to correctly identify individual tastes shows that gender influenced the ability to identify sweet and bitter tastes. Statistically, significantly more men incorrectly identified these flavors.
4. The impact of the infection and course of COVID-19 on the ability to identify the analyzed flavors was moderate and was only marked by a higher share of people incorrectly identifying the bitter taste. Subjects who lost their sense of smell were statistically significantly more likely to incorrectly identify salty and bitter tastes.
5. Based on conducted research it was observed that as a result of COVID-19 illness the quality of life expressed as taste and/or smell lose which occurred in the group of students that were exposed to COVID-19 decreased.

Founding source: The research was conducted based on own resources of Rzeszow University of Technology.

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